1
00:00:00,000 --> 00:00:07,528
our talk tonight is the life cycle of

2
00:00:02,908 --> 00:00:08,820
dust in galaxies we have an astronomer

3
00:00:07,528 --> 00:00:11,939
in the office of public outreach who

4
00:00:08,820 --> 00:00:13,289
studies dust and I got to say that some

5
00:00:11,939 --> 00:00:14,669
of the other astronomers you know give

6
00:00:13,289 --> 00:00:16,528
him a little bit of a hard time like aha

7
00:00:14,669 --> 00:00:17,879
you're looking at dust out there you

8
00:00:16,528 --> 00:00:21,000
know a can a pledge could wipe you out

9
00:00:17,879 --> 00:00:22,469
well this is actually one of the most

10
00:00:21,000 --> 00:00:24,390
important things in astronomy and

11
00:00:22,469 --> 00:00:26,698
Margaret will be able to show you if the

12
00:00:24,390 --> 00:00:30,390
splendors of dust in the universe

13
00:00:26,699 --> 00:00:32,910
tonight upcoming next month Tom Brown

14
00:00:30,390 --> 00:00:34,409
who was a gracious and postponed news

15
00:00:32,909 --> 00:00:36,629
talk when we had a special guest speaker

16
00:00:34,409 --> 00:00:39,000
a few months ago will talk about on the

17
00:00:36,630 --> 00:00:42,450
trail of the missing galaxies the oldest

18
00:00:39,000 --> 00:00:45,988
stars in the neighborhood in our local

19
00:00:42,450 --> 00:00:48,149
galactic neighborhood October Bill Blair

20
00:00:45,988 --> 00:00:51,149
of from across the street Johns Hopkins

21
00:00:48,149 --> 00:00:54,179
will do present a multi-wavelength view

22
00:00:51,149 --> 00:00:56,509
of stellar life and death in Messier 83

23
00:00:54,179 --> 00:00:58,738
or another talk actually he had about

24
00:00:56,509 --> 00:01:00,988
writing another title he had like four

25
00:00:58,738 --> 00:01:02,729
different titles he was suggesting this

26
00:01:00,988 --> 00:01:04,170
is the one that I said oh this sounds

27
00:01:02,729 --> 00:01:05,368
good bill but he hasn't got back to me

28
00:01:04,170 --> 00:01:08,280
as to which one you'll actually choose

29

00:01:05,368 --> 00:01:11,368
but it'll be about supernovae in the

30
00:01:08,280 --> 00:01:13,670
galaxy Messier 83 in November

31
00:01:11,368 --> 00:01:16,950
unfortunately our speaker TVA is back

32
00:01:13,670 --> 00:01:19,799
and he keeps popping up every now and

33
00:01:16,950 --> 00:01:21,930
then this I will note is on November 1st

34
00:01:19,799 --> 00:01:24,299
it's not on election night election

35
00:01:21,930 --> 00:01:25,860
night will be November 8th so the week

36
00:01:24,299 --> 00:01:28,229
before election night maybe we're gonna

37
00:01:25,859 --> 00:01:30,659
have a debate you know no no no no

38
00:01:28,228 --> 00:01:33,509
absolutely not we don't do politics here

39
00:01:30,659 --> 00:01:35,640
but please come the week before you vote

40
00:01:33,509 --> 00:01:38,930
to our public lecture series

41
00:01:35,640 --> 00:01:42,450
I'll have that speaker for you in a bit

42
00:01:38,930 --> 00:01:44,368
deconstruction as you know San Martin

43
00:01:42,450 --> 00:01:47,159

drives south of STScI will be closed

44
00:01:44,368 --> 00:01:49,200
until approximately September 2016

45
00:01:47,159 --> 00:01:51,000
so to get here tonight you had to

46
00:01:49,200 --> 00:01:53,250
approach STS yeah I from the north

47
00:01:51,000 --> 00:01:56,879
however you'll notice that September

48
00:01:53,250 --> 00:01:59,578
2016 so by the next month things might

49
00:01:56,879 --> 00:02:01,890
have changed if you go to this website

50
00:01:59,578 --> 00:02:05,179
it says that phase 1 is scheduled to be

51
00:02:01,890 --> 00:02:08,068
completed the end of August with phase 2

52
00:02:05,180 --> 00:02:11,370
to begin immediately afterward that

53
00:02:08,068 --> 00:02:13,799
means that next time we have this it

54
00:02:11,370 --> 00:02:15,990
could be see all this

55
00:02:13,800 --> 00:02:18,300
stuff here that's currently closed it

56
00:02:15,990 --> 00:02:21,150
could be then that then the red stuff

57
00:02:18,300 --> 00:02:22,800
and the yellow stuff will be closed so

58
00:02:21,150 --> 00:02:25,650
instead of coming from University

59
00:02:22,800 --> 00:02:28,560
Parkway south to STScI you will have to

60
00:02:25,650 --> 00:02:31,650
come from Wyman Park Drive to come north

61
00:02:28,560 --> 00:02:34,199
to us okay so approach us from the south

62
00:02:31,650 --> 00:02:36,330
so next month I expect I will have this

63
00:02:34,199 --> 00:02:38,639
one that between September and December

64
00:02:36,330 --> 00:02:41,760
the north part will be closed so

65
00:02:38,639 --> 00:02:44,729
approach from Wyman Park Drive if you

66
00:02:41,759 --> 00:02:46,859
are on our email list I will the day or

67
00:02:44,729 --> 00:02:48,869
both of the lecture or before the

68
00:02:46,860 --> 00:02:50,730
lecture make sure that you get the

69
00:02:48,870 --> 00:02:52,890
proper instructions as to whether come

70
00:02:50,729 --> 00:02:55,379
from the north or from the South okay or

71
00:02:52,889 --> 00:02:58,679
you can just to check this website for

72
00:02:55,379 --> 00:03:02,039
yourself our website where you get

73
00:02:58,680 --> 00:03:03,629
information like this is well if you

74
00:03:02,039 --> 00:03:04,949
just search Hubble public talks you'll

75
00:03:03,629 --> 00:03:07,469
find it in your favorite search engine

76
00:03:04,949 --> 00:03:09,810
at Hubble site we have a Golding Hubble

77
00:03:07,469 --> 00:03:12,900
site or go talks you get the list of the

78
00:03:09,810 --> 00:03:16,289
upcoming lectures you have links to the

79
00:03:12,900 --> 00:03:18,930
live YouTube and STS a webcasting feeds

80
00:03:16,289 --> 00:03:21,870
as well as the past lectures on YouTube

81
00:03:18,930 --> 00:03:24,900
and the STS a webcasting and the easiest

82
00:03:21,870 --> 00:03:27,239
way to sign up for our email list you

83
00:03:24,900 --> 00:03:30,989
can subscribe or even unsubscribe here

84
00:03:27,239 --> 00:03:33,090
all right our e-mail announcements if

85
00:03:30,989 --> 00:03:35,489
you don't want to use our web page can

86

00:03:33,090 --> 00:03:39,090
be found at mail list at stsci dot edu

87
00:03:35,489 --> 00:03:41,629
is called public lecture announce last

88
00:03:39,090 --> 00:03:44,580
thing if you have questions or cut

89
00:03:41,629 --> 00:03:46,799
social media we are on Facebook we had

90
00:03:44,580 --> 00:03:49,610
two Twitter accounts we're on Google+

91
00:03:46,800 --> 00:03:53,610
we have Pinterest I'm also on Facebook

92
00:03:49,610 --> 00:03:58,380
Google+ and Twitter occasionally and I

93
00:03:53,610 --> 00:04:00,480
have a blog on Hubbell site alright

94
00:03:58,379 --> 00:04:02,789
the observatory the weather appears to

95
00:04:00,479 --> 00:04:04,889
be permitting so it looks like there

96
00:04:02,789 --> 00:04:06,989
will be observing tonight this is the

97
00:04:04,889 --> 00:04:08,579
Maryland Space Grant Observatory which

98
00:04:06,989 --> 00:04:10,650
is on top of the physics and astronomy

99
00:04:08,580 --> 00:04:12,600
building across the street here in

100
00:04:10,650 --> 00:04:16,139

Hopkins so you can go up and do a little

101
00:04:12,599 --> 00:04:18,298
bit observing afterwards Duncan will

102
00:04:16,139 --> 00:04:20,279
probably be here at the end if I forget

103
00:04:18,298 --> 00:04:22,228
somebody remind me hey hey what about

104
00:04:20,279 --> 00:04:24,329
the observing because you'll just sort

105
00:04:22,228 --> 00:04:26,538
of meet if you cannot go over by

106
00:04:24,329 --> 00:04:28,050
yourself you got to go over with Duncan

107
00:04:26,538 --> 00:04:30,509
because you got

108
00:04:28,050 --> 00:04:31,889
through some some get into the building

109
00:04:30,509 --> 00:04:34,729
and through some stairs and up and you

110
00:04:31,889 --> 00:04:38,550
have to go as a group okay all right

111
00:04:34,728 --> 00:04:40,589
news from the universe for August 2016

112
00:04:38,550 --> 00:04:42,270
and I will apologize it's gonna be a

113
00:04:40,589 --> 00:04:43,589
little abbreviated because we've been

114
00:04:42,269 --> 00:04:45,299
really busy in the office of public

115
00:04:43,589 --> 00:04:47,219
outreach lately I didn't have enough

116
00:04:45,300 --> 00:04:49,098
time to prepare full stories but I do

117
00:04:47,220 --> 00:04:53,009
have two short stories for you tonight

118
00:04:49,098 --> 00:04:58,529
our first story the final frontier of

119
00:04:53,009 --> 00:05:00,270
the universe if you keep up with popular

120
00:04:58,529 --> 00:05:04,168
culture you know that this year is the

121
00:05:00,269 --> 00:05:07,348
50th anniversary of Star Trek the Star

122
00:05:04,168 --> 00:05:09,120
Trek series 50 years ago how many

123
00:05:07,348 --> 00:05:13,379
seasons did the original Star Trek TV

124
00:05:09,120 --> 00:05:15,990
show last just three it's amazing that

125
00:05:13,379 --> 00:05:17,908
this franchise has lasted so long but

126
00:05:15,990 --> 00:05:22,199
the original TV series is only three

127
00:05:17,908 --> 00:05:24,629
seasons well we here at Hubble and NASA

128
00:05:22,199 --> 00:05:28,009
like to get in on a good pop culture

129
00:05:24,629 --> 00:05:30,149
reference so well we don't have

130
00:05:28,009 --> 00:05:33,330
spaceships that can explore the universe

131
00:05:30,149 --> 00:05:37,228
we don't have warp drive to boost us to

132
00:05:33,329 --> 00:05:39,508
the far side of the galaxy but we do

133
00:05:37,228 --> 00:05:43,228
explore the universe and we use a

134
00:05:39,509 --> 00:05:46,979
version of nature's own warp drive what

135
00:05:43,228 --> 00:05:49,500
we do have is gravitational lensing the

136
00:05:46,978 --> 00:05:51,959
mass of giant clusters of galaxies

137
00:05:49,500 --> 00:05:55,848
actually warps the fabric of space

138
00:05:51,959 --> 00:05:58,468
around them and using that spatial warp

139
00:05:55,848 --> 00:06:02,459
the light that passes through it is

140
00:05:58,468 --> 00:06:07,129
redirected such that the light actually

141
00:06:02,459 --> 00:06:09,180
lens acts like a lens and focuses and

142
00:06:07,129 --> 00:06:13,228
amplifies the light that passes through

143

00:06:09,180 --> 00:06:15,598
it so we have gravitational lensing that

144
00:06:13,228 --> 00:06:18,149
we can use to look at the most distant

145
00:06:15,598 --> 00:06:20,759
regions of universe and we have done so

146
00:06:18,149 --> 00:06:24,269
in a project called the frontier fields

147
00:06:20,759 --> 00:06:27,210
and for the press release that we did

148
00:06:24,269 --> 00:06:28,859
celebrating in honor of stark the new

149
00:06:27,209 --> 00:06:31,589
Star Trek movie in Star Trek's 50th

150
00:06:28,860 --> 00:06:36,149
anniversary we released the last the

151
00:06:31,589 --> 00:06:40,319
final of our frontier fields a bell s106

152
00:06:36,149 --> 00:06:41,990
3 so what you are seeing here is this

153
00:06:40,319 --> 00:06:44,750
giant cluster of

154
00:06:41,990 --> 00:06:47,689
sees all these galaxies here that are so

155
00:06:44,750 --> 00:06:50,629
massive - combined that they warp the

156
00:06:47,689 --> 00:06:52,219
space around it and then the galaxies

157
00:06:50,629 --> 00:06:54,529

that are behind it the light that passes

158
00:06:52,220 --> 00:06:57,200
through gets warped it becomes distorted

159
00:06:54,529 --> 00:06:59,659
you can see these long streaky Archy

160
00:06:57,199 --> 00:07:02,180
things those are gravitationally lens

161
00:06:59,660 --> 00:07:04,189
arcs they are the images of galaxies

162
00:07:02,180 --> 00:07:05,660
behind the cluster that have become

163
00:07:04,189 --> 00:07:08,449
stretched out as the light passes

164
00:07:05,660 --> 00:07:08,689
through that cluster of galaxies all

165
00:07:08,449 --> 00:07:11,509
right

166
00:07:08,689 --> 00:07:14,060
it also amplifies the light makes it

167
00:07:11,509 --> 00:07:16,579
brighter so that we can see fainter

168
00:07:14,060 --> 00:07:19,879
galaxies by looking through this cluster

169
00:07:16,579 --> 00:07:21,620
than we otherwise could all right the

170
00:07:19,879 --> 00:07:24,139
frontier fields project is one of the

171
00:07:21,620 --> 00:07:27,139
largest projects ever to get time on

172
00:07:24,139 --> 00:07:30,259
Hubble and it not only observes these

173
00:07:27,139 --> 00:07:31,339
giant clusters but while one instrument

174
00:07:30,259 --> 00:07:34,039
is observing these giant clusters

175
00:07:31,339 --> 00:07:36,739
another instrument is observing a random

176
00:07:34,040 --> 00:07:39,140
field relatively nearby and so we also

177
00:07:36,740 --> 00:07:42,230
have these deep fields that we can

178
00:07:39,139 --> 00:07:44,539
release because we process two images at

179
00:07:42,230 --> 00:07:46,879
the same time one of the cluster one of

180
00:07:44,540 --> 00:07:49,520
this parallel field and these parallel

181
00:07:46,879 --> 00:07:51,649
fields are very deep images of the night

182
00:07:49,519 --> 00:07:55,250
skies like the Hubble Deep Field and

183
00:07:51,649 --> 00:07:58,339
Hubble ultra-deep field so using the

184
00:07:55,250 --> 00:08:01,160
nature's warp drive we are exploring the

185
00:07:58,339 --> 00:08:03,799
frontiers of the universe with the

186
00:08:01,160 --> 00:08:06,620
frontier fields project and if you think

187
00:08:03,800 --> 00:08:08,210
that sort of play on words was bad you

188
00:08:06,620 --> 00:08:10,459
ought to read the press releases because

189
00:08:08,209 --> 00:08:12,889
they gets really bad in terms of trying

190
00:08:10,459 --> 00:08:14,989
to use the play on words but there was a

191
00:08:12,889 --> 00:08:17,569
way of connecting with the the Star Trek

192
00:08:14,990 --> 00:08:19,790
50th anniversary and showing off the

193
00:08:17,569 --> 00:08:20,810
deep deep images we are getting of the

194
00:08:19,790 --> 00:08:24,800
universe with the frontier fields

195
00:08:20,810 --> 00:08:28,459
project our second story tonight is

196
00:08:24,800 --> 00:08:31,730
about the heart of the Crab Nebula now

197
00:08:28,459 --> 00:08:34,750
in 2000 or 2001 we released this image

198
00:08:31,730 --> 00:08:37,850
of the Crab Nebula the Crab Nebula is a

199
00:08:34,750 --> 00:08:39,799
supernova remnant this is a star that

200

00:08:37,850 --> 00:08:42,529
was observed by chinese astronomers to

201
00:08:39,799 --> 00:08:45,969
have exploded from our point of view a

202
00:08:42,529 --> 00:08:49,399
thousand years ago we saw the star

203
00:08:45,970 --> 00:08:51,139
brightened a thousand years ago it was

204
00:08:49,399 --> 00:08:53,689
bright enough to be observed in the

205
00:08:51,139 --> 00:08:54,449
daytime for about a month okay

206
00:08:53,690 --> 00:08:56,100
and

207
00:08:54,450 --> 00:08:58,230
we look in that same spot in the sky

208
00:08:56,100 --> 00:09:00,000
these days this is what we see we see

209
00:08:58,230 --> 00:09:02,909
the guts of the star just blown out

210
00:09:00,000 --> 00:09:05,759
across space and so this is Hubble's

211
00:09:02,909 --> 00:09:08,370
image from but this is probably this is

212
00:09:05,759 --> 00:09:10,649
a with pictu image of the Crab Nebula

213
00:09:08,370 --> 00:09:12,529
and you can see all of the the material

214
00:09:10,649 --> 00:09:15,659

of the star that blows out into space

215
00:09:12,529 --> 00:09:17,970
now at the center of the Crab Nebula the

216
00:09:15,659 --> 00:09:21,299
beating heart of the Crab Nebula is

217
00:09:17,970 --> 00:09:24,000
something called a pulsar and so we just

218
00:09:21,299 --> 00:09:26,219
released in this month this image of a

219
00:09:24,000 --> 00:09:28,409
core of the Crab Nebula all right you

220
00:09:26,220 --> 00:09:30,690
can see that filamentary structure but

221
00:09:28,409 --> 00:09:33,000
you can also see these rings around here

222
00:09:30,690 --> 00:09:36,420
circling around at the center which is

223
00:09:33,000 --> 00:09:39,570
where the pulsar is now a pulsar is a

224
00:09:36,419 --> 00:09:42,569
neutron star that is spinning okay and a

225
00:09:39,570 --> 00:09:44,700
neutron star is basically an atomic

226
00:09:42,570 --> 00:09:47,460
nucleus all right that weighs as much as

227
00:09:44,700 --> 00:09:49,320
the Sun right because all of the

228
00:09:47,460 --> 00:09:51,990
material at the end of the supernova

229
00:09:49,320 --> 00:09:54,450
explosion collapses that the core of it

230
00:09:51,990 --> 00:09:57,779
collapses to become there's really super

231
00:09:54,450 --> 00:10:00,780
dense neutron star at the core and it is

232
00:09:57,779 --> 00:10:03,799
spinning so fast that the heart of the

233
00:10:00,779 --> 00:10:06,899
crowd nebula spins 30 times every second

234
00:10:03,799 --> 00:10:12,179
this was a signal that was discovered by

235
00:10:06,899 --> 00:10:13,199
radio astronomers in 1960 1961 called

236
00:10:12,179 --> 00:10:16,489
lgm1

237
00:10:13,200 --> 00:10:19,050
as in little green men number one

238
00:10:16,490 --> 00:10:21,779
because we didn't know what it was back

239
00:10:19,049 --> 00:10:24,240
in the 60s we now know that it is a

240
00:10:21,779 --> 00:10:26,939
neutron star spinning 30 times a second

241
00:10:24,240 --> 00:10:29,190
and it has intense intense magnetic

242
00:10:26,940 --> 00:10:31,410
field and here you can actually see the

243
00:10:29,190 --> 00:10:33,750
rings around here our material that is

244
00:10:31,409 --> 00:10:36,569
actually moving away and you can see the

245
00:10:33,750 --> 00:10:37,889
material and we actually have time-lapse

246
00:10:36,570 --> 00:10:40,650
of this where we can actually watch the

247
00:10:37,889 --> 00:10:42,600
material move away from the Crab Nebula

248
00:10:40,649 --> 00:10:44,879
one of the few things in astronomy that

249
00:10:42,600 --> 00:10:48,300
changes during our lifetime

250
00:10:44,879 --> 00:10:50,970
there was no science new science result

251
00:10:48,299 --> 00:10:52,829
released with this image this was just a

252
00:10:50,970 --> 00:10:56,910
reprocessing of other data that we had

253
00:10:52,830 --> 00:11:00,270
gotten but going in deeper and seeing

254
00:10:56,909 --> 00:11:02,339
the heart of the Crab Nebula okay that

255
00:11:00,269 --> 00:11:05,029
was our Hubble heritage release for July

256
00:11:02,340 --> 00:11:05,030
question

257

00:11:10,039 --> 00:11:16,949
well if I go back to this image the

258
00:11:12,899 --> 00:11:18,990
neutron star is about in here okay

259
00:11:16,950 --> 00:11:20,940
the two images are actually at slightly

260
00:11:18,990 --> 00:11:24,149
different orientation okay I think the

261
00:11:20,940 --> 00:11:26,910
the image is rotated about 110 degrees

262
00:11:24,149 --> 00:11:28,049
from from this image I was gonna line

263
00:11:26,909 --> 00:11:31,350
them up but I didn't quite have time

264
00:11:28,049 --> 00:11:33,509
today to do that sorry about right but

265
00:11:31,350 --> 00:11:36,540
yeah it is it is it is in the in the

266
00:11:33,509 --> 00:11:40,830
core of that by the way this nebula here

267
00:11:36,539 --> 00:11:43,049
is about ten light years across okay so

268
00:11:40,830 --> 00:11:45,360
it's gone from being a single star to

269
00:11:43,049 --> 00:11:48,409
being about ten light years across over

270
00:11:45,360 --> 00:11:51,779
the course of a thousand years all right

271
00:11:48,409 --> 00:11:55,110

okay so now we go to our featured

272
00:11:51,779 --> 00:11:57,899
speaker and our featured speaker tonight

273
00:11:55,110 --> 00:12:00,180
is Margaret Meixner she and I first met

274
00:11:57,899 --> 00:12:02,610
at the University of California Berkeley

275
00:12:00,179 --> 00:12:04,859
where we were doing our graduate school

276
00:12:02,610 --> 00:12:07,980
together back at Berkeley they're

277
00:12:04,860 --> 00:12:09,930
actually several from from our group of

278
00:12:07,980 --> 00:12:11,009
astronomers going through grad students

279
00:12:09,929 --> 00:12:12,839
going through Berkeley that are working

280
00:12:11,009 --> 00:12:14,460
here at Space Telescope so obviously we

281
00:12:12,840 --> 00:12:17,340
were just an amazing group of grad

282
00:12:14,460 --> 00:12:20,790
students right several of us ended up

283
00:12:17,340 --> 00:12:23,190
here Margaret however was Mark was the

284
00:12:20,789 --> 00:12:26,490
most exceptional of all of us as

285
00:12:23,190 --> 00:12:30,870
evidenced by after she graduated and got

286
00:12:26,490 --> 00:12:32,909
her PhD she didn't go to a postdoc she

287
00:12:30,870 --> 00:12:34,679
was offered an associate assistant

288
00:12:32,909 --> 00:12:36,659
professorship at the University of

289
00:12:34,679 --> 00:12:39,179
Illinois she went straight from grad

290
00:12:36,659 --> 00:12:41,669
school to being a professor that just

291
00:12:39,179 --> 00:12:42,769
almost never happens okay that tells you

292
00:12:41,669 --> 00:12:44,819
how special she is

293
00:12:42,769 --> 00:12:47,939
fortunately University of Illinois

294
00:12:44,820 --> 00:12:49,770
couldn't keep her alright and in 2002

295
00:12:47,940 --> 00:12:52,350
she came here to the whole Space

296
00:12:49,769 --> 00:12:54,120
Telescope Science Institute and has been

297
00:12:52,350 --> 00:12:59,310
here for I guess 14 years now that makes

298
00:12:54,120 --> 00:13:02,519
it yeah she is an expert in dust of

299
00:12:59,309 --> 00:13:05,009
course but she's also really really good

300
00:13:02,519 --> 00:13:08,220
at doing very large observations very

301
00:13:05,009 --> 00:13:09,980
large survey observations the last talk

302
00:13:08,220 --> 00:13:12,840
you gave here was on planetary nebula

303
00:13:09,980 --> 00:13:15,690
right but you've gay you've done since

304
00:13:12,840 --> 00:13:17,939
then done a number of very large surveys

305
00:13:15,690 --> 00:13:19,349
and she's done them so well

306
00:13:17,938 --> 00:13:21,149
they've actually made her put her in

307
00:13:19,349 --> 00:13:23,789
charge a lot of things and her current

308
00:13:21,149 --> 00:13:25,078
position as as deputy of the instruments

309
00:13:23,788 --> 00:13:27,178
division here

310
00:13:25,078 --> 00:13:28,918
I think she's pleased to be able to talk

311
00:13:27,178 --> 00:13:30,899
about the science work that she loves so

312
00:13:28,918 --> 00:13:48,720
much so ladies and gentlemen dr.

313
00:13:30,899 --> 00:13:50,249
Margaret Meixner can you hear me if you

314

00:13:48,720 --> 00:13:54,329
can in the back wave your hand

315
00:13:50,249 --> 00:13:56,699
all right good all right so I'm gonna

316
00:13:54,328 --> 00:13:59,488
talk to you about the life cycle of dust

317
00:13:56,698 --> 00:14:02,008
and galaxies and the subtitle here is

318
00:13:59,489 --> 00:14:03,859
from these large surveys that Frank was

319
00:14:02,009 --> 00:14:06,678
telling you that I that I'd love to do

320
00:14:03,859 --> 00:14:09,418
insights from Spitzer and Herschel

321
00:14:06,678 --> 00:14:13,470
Spitzer and Herschel are two infrared

322
00:14:09,418 --> 00:14:16,619
space observatories that flew Spitzer

323
00:14:13,470 --> 00:14:18,418
Stoll still out there and I used it to

324
00:14:16,619 --> 00:14:19,408
survey the Magellanic Clouds how many

325
00:14:18,418 --> 00:14:27,149
people have heard of the Magellanic

326
00:14:19,408 --> 00:14:28,470
Clouds before Wow very well all right so

327
00:14:27,149 --> 00:14:31,009
this is a picture of the Large

328
00:14:28,470 --> 00:14:38,189

Magellanic Cloud that's a combination of

329
00:14:31,009 --> 00:14:39,869
both Spitzer and Herschel data and it

330
00:14:38,188 --> 00:14:42,509
looks very disc II it has all this

331
00:14:39,869 --> 00:14:45,199
frothy very colorful things and I look

332
00:14:42,509 --> 00:14:50,308
at it it's like wow this is beautiful

333
00:14:45,198 --> 00:14:52,139
isn't that beautiful and I look at it I

334
00:14:50,308 --> 00:14:54,448
said this is beautiful but I can't help

335
00:14:52,139 --> 00:14:56,188
but thinking about all the dust that's

336
00:14:54,448 --> 00:14:57,658
in it that's causing it because all this

337
00:14:56,188 --> 00:15:01,108
emission you see here is actually from

338
00:14:57,658 --> 00:15:03,178
the dust in these galaxies in particular

339
00:15:01,109 --> 00:15:08,668
I asked myself the question of why does

340
00:15:03,178 --> 00:15:10,288
this galaxy have dust because as you may

341
00:15:08,668 --> 00:15:12,119
have heard in these forums the whole

342
00:15:10,288 --> 00:15:13,889
universe began is mostly hydrogen and

343
00:15:12,119 --> 00:15:16,349
helium it may be a few other elements

344
00:15:13,889 --> 00:15:20,038
but we've got dust now so how did it get

345
00:15:16,349 --> 00:15:22,589
there so what I'm gonna be talking to

346
00:15:20,038 --> 00:15:24,028
you about is the life cycle of dust in

347
00:15:22,589 --> 00:15:27,779
galaxies and I'm going to use this

348
00:15:24,028 --> 00:15:30,058
cartoon to describe how dust gets there

349
00:15:27,778 --> 00:15:30,759
or the processes in there and also how

350
00:15:30,058 --> 00:15:33,639
much

351
00:15:30,759 --> 00:15:34,990
a little we know about it so let me go

352
00:15:33,639 --> 00:15:36,610
through this because I'm gonna use this

353
00:15:34,990 --> 00:15:40,240
as a narrative tool throughout the whole

354
00:15:36,610 --> 00:15:43,539
talk so at the center here we have what

355
00:15:40,240 --> 00:15:46,000
I call the origin of dust so dust can be

356
00:15:43,539 --> 00:15:48,610
formed in the atmospheres of AGB stars

357
00:15:46,000 --> 00:15:50,590
so AG B stands for asymptotic giant

358
00:15:48,610 --> 00:15:53,169
branch stars these are dying stars like

359
00:15:50,590 --> 00:15:57,490
our Sun will become an Ag B star and

360
00:15:53,169 --> 00:15:59,829
they blow winds and send out dust dust

361
00:15:57,490 --> 00:16:01,120
dust may also arise in supernovae so

362
00:15:59,830 --> 00:16:04,270
Frank just talked to you about the Crab

363
00:16:01,120 --> 00:16:07,450
Nebula the crab has dust in it and

364
00:16:04,269 --> 00:16:10,269
that's the pipe to supernova that's when

365
00:16:07,450 --> 00:16:13,450
a massive star explodes type 1a

366
00:16:10,269 --> 00:16:14,829
supernovas are being looked at but

367
00:16:13,450 --> 00:16:16,990
there's that's more like a white dwarf

368
00:16:14,830 --> 00:16:19,509
pair exploding so anyway these are where

369
00:16:16,990 --> 00:16:21,639
the new grains come from and they get

370
00:16:19,509 --> 00:16:26,049
injected out drifts out into the

371

00:16:21,639 --> 00:16:28,210
interstellar medium and they're in the

372
00:16:26,049 --> 00:16:30,939
interstellar medium they get processed a

373
00:16:28,210 --> 00:16:33,220
lot so these same supernovae that create

374
00:16:30,940 --> 00:16:34,900
dust will also send huge shock waves in

375
00:16:33,220 --> 00:16:38,170
the interstellar medium and they'll

376
00:16:34,899 --> 00:16:40,419
shatter the grains and then these grains

377
00:16:38,169 --> 00:16:42,819
will drift around because the is M

378
00:16:40,419 --> 00:16:48,009
drifts around into the inter cloud

379
00:16:42,820 --> 00:16:49,900
medium clouds will form out of these and

380
00:16:48,009 --> 00:16:53,049
the dust kind of gets dragged along with

381
00:16:49,899 --> 00:16:55,539
the gas in there and then they become

382
00:16:53,049 --> 00:16:59,199
cold clouds and maybe in the cold clouds

383
00:16:55,539 --> 00:17:01,329
you get growth of dust that as the

384
00:16:59,200 --> 00:17:03,490
grains grow bigger because they're cold

385
00:17:01,330 --> 00:17:05,730

and they get Mantle's around them and

386
00:17:03,490 --> 00:17:08,410
maybe they just start sticking and grow

387
00:17:05,730 --> 00:17:11,349
and then from and then this this whole

388
00:17:08,410 --> 00:17:13,779
cycle out here the is M can happen

389
00:17:11,349 --> 00:17:16,599
around but also from these dense clouds

390
00:17:13,779 --> 00:17:19,690
you can form young stars and so young

391
00:17:16,599 --> 00:17:21,490
stars form and then you know they they

392
00:17:19,690 --> 00:17:23,920
grow up to main sequence stars and then

393
00:17:21,490 --> 00:17:25,209
the whole process to Stiles starts over

394
00:17:23,920 --> 00:17:28,560
again so that's why we call it a life

395
00:17:25,209 --> 00:17:31,539
cycle because stars have a life cycle

396
00:17:28,559 --> 00:17:33,190
and because stars have a life cycle on

397
00:17:31,539 --> 00:17:37,920
the air in some sense the sources and

398
00:17:33,190 --> 00:17:37,920
sinks of dust I'm Duff has a life cycle

399
00:17:38,410 --> 00:17:42,380
all right so let me talk a little bit

400
00:17:40,789 --> 00:17:46,730
about the Magellanic Clouds and why I

401
00:17:42,380 --> 00:17:49,310
chose them for this study first of all

402
00:17:46,730 --> 00:17:51,620
they're nearby so so proximity is

403
00:17:49,309 --> 00:17:55,579
helpful the Large Magellanic Clouds

404
00:17:51,619 --> 00:17:58,759
about 50 kiloparsecs away the small

405
00:17:55,579 --> 00:18:00,799
Magellanic Clouds about 60 and you

406
00:17:58,759 --> 00:18:03,019
multiply that by kind of 3.3 to get

407
00:18:00,799 --> 00:18:05,000
light-years but if you can ever go to

408
00:18:03,019 --> 00:18:06,680
the southern hemisphere you can see the

409
00:18:05,000 --> 00:18:08,119
Magellanic Clouds with your own eye at

410
00:18:06,680 --> 00:18:12,350
night it's quite a sight they're

411
00:18:08,119 --> 00:18:14,829
beautiful visions to see the Large

412
00:18:12,349 --> 00:18:17,899
Magellanic Cloud which I'm going to be

413
00:18:14,829 --> 00:18:19,669
because I am affiliated with NASA I love

414
00:18:17,900 --> 00:18:21,920
acronyms so I'm going to call it LM C

415
00:18:19,670 --> 00:18:23,420
for Large Magellanic Clouds it's kind of

416
00:18:21,920 --> 00:18:24,500
nearly face on remember that first

417
00:18:23,420 --> 00:18:27,680
picture I showed you is kind of

418
00:18:24,500 --> 00:18:29,480
disc-like so it's nearly face on and the

419
00:18:27,680 --> 00:18:31,220
combination of both these things the

420
00:18:29,480 --> 00:18:33,700
fact that they're kind of close by and

421
00:18:31,220 --> 00:18:37,360
the LM scene particulars kind of face on

422
00:18:33,700 --> 00:18:40,340
you can separate the stars from the

423
00:18:37,359 --> 00:18:42,529
interstellar clouds and then watch their

424
00:18:40,339 --> 00:18:44,240
in monitor their interaction between

425
00:18:42,529 --> 00:18:47,210
each other because you can separate them

426
00:18:44,240 --> 00:18:48,680
and because it's nearly face-on you can

427
00:18:47,210 --> 00:18:50,240
kind of look at a dust cloud and say

428

00:18:48,680 --> 00:18:51,740
well I think it's really associated with

429
00:18:50,240 --> 00:18:55,579
this gas cloud and stuff so there's a

430
00:18:51,740 --> 00:18:58,490
lot of clarity and information you can

431
00:18:55,579 --> 00:19:00,649
get from these from these systems now

432
00:18:58,490 --> 00:19:02,210
the Magellanic Clouds are I've been

433
00:19:00,650 --> 00:19:04,120
interested for a lot of reasons

434
00:19:02,210 --> 00:19:06,410
throughout the the history of astronomy

435
00:19:04,119 --> 00:19:09,879
they're sort of a stepping stone between

436
00:19:06,410 --> 00:19:13,130
galactic and extra galactic studies

437
00:19:09,880 --> 00:19:15,740
they're mean metallicity which means how

438
00:19:13,130 --> 00:19:19,940
many metals and metals is anything

439
00:19:15,740 --> 00:19:23,480
heavier than helium really is the LMC

440
00:19:19,940 --> 00:19:26,059
it's about 1/2 solar so it's less half

441
00:19:23,480 --> 00:19:28,279
half of the metallicity of our own Sun

442
00:19:26,059 --> 00:19:30,470

in our own solar system and the small

443
00:19:28,279 --> 00:19:33,710
Magellanic Cloud is 0.2 times that's

444
00:19:30,470 --> 00:19:35,990
sort of 1/5 so it's less and this

445
00:19:33,710 --> 00:19:39,319
metallicity is interesting because the

446
00:19:35,990 --> 00:19:42,740
is Emer the interstellar medium in the

447
00:19:39,319 --> 00:19:45,379
universe had a in in galaxies in the

448
00:19:42,740 --> 00:19:49,460
universe had a peak star formation epoch

449
00:19:45,380 --> 00:19:50,680
and a Z about 1.5 but the mean

450
00:19:49,460 --> 00:19:54,400
mentallity the Magellanic

451
00:19:50,680 --> 00:19:55,990
is actually brackets what happened

452
00:19:54,400 --> 00:19:58,660
during the peak star formation effect so

453
00:19:55,990 --> 00:20:00,250
if you study sort of the Astrophysical

454
00:19:58,660 --> 00:20:01,540
processes in the Magellanic Clouds you

455
00:20:00,250 --> 00:20:03,490
might get some insight of what was

456
00:20:01,539 --> 00:20:06,670
happening during this major event in our

457
00:20:03,490 --> 00:20:09,519
universe of star formation and then the

458
00:20:06,670 --> 00:20:13,779
dust content that is what we call the

459
00:20:09,519 --> 00:20:17,349
dust to gas ratio is lower than our own

460
00:20:13,779 --> 00:20:20,649
galaxy again about half the Milky of the

461
00:20:17,349 --> 00:20:25,029
Milky Way's dust content and for the SMC

462
00:20:20,650 --> 00:20:26,950
it's about a tenth and then some other

463
00:20:25,029 --> 00:20:29,440
interesting aspects to the large and

464
00:20:26,950 --> 00:20:31,150
small Magellanic Cloud have known tidal

465
00:20:29,440 --> 00:20:35,440
interactions between each other there

466
00:20:31,150 --> 00:20:38,200
they're a pair and possibly the Milky

467
00:20:35,440 --> 00:20:40,750
Way and they've had a very long history

468
00:20:38,200 --> 00:20:42,370
of studies of all sorts of studies

469
00:20:40,750 --> 00:20:44,619
they've been a proving ground for lots

470
00:20:42,369 --> 00:20:46,599
of studies I mean for example the whole

471
00:20:44,619 --> 00:20:48,699
thing is cepheid's relation which people

472
00:20:46,599 --> 00:20:50,169
use for distance indicators that was

473
00:20:48,700 --> 00:20:53,470
first established in the Magellanic

474
00:20:50,170 --> 00:20:56,769
Clouds and so for a member of reasons

475
00:20:53,470 --> 00:21:03,910
this is sort of an ideal case study for

476
00:20:56,769 --> 00:21:07,420
galaxy evolution alright so what I did

477
00:21:03,910 --> 00:21:09,460
is I led to large surveys and the work

478
00:21:07,420 --> 00:21:11,650
I'm showing is actually from a team of

479
00:21:09,460 --> 00:21:15,490
sort of over a hundred scientists

480
00:21:11,650 --> 00:21:18,400
worldwide but I helped I helped organize

481
00:21:15,490 --> 00:21:20,349
the effort with Spitzer we call that

482
00:21:18,400 --> 00:21:22,269
surveying the agents of galaxy evolution

483
00:21:20,349 --> 00:21:24,849
the agents are the stars in the

484
00:21:22,269 --> 00:21:27,250
interstellar medium that really create

485

00:21:24,849 --> 00:21:29,049
the environment and we also called it

486
00:21:27,250 --> 00:21:30,789
the Herschel inventory of the agents of

487
00:21:29,049 --> 00:21:34,690
galaxy evolution so we call them sage

488
00:21:30,789 --> 00:21:36,730
and heritage and what we have here are

489
00:21:34,690 --> 00:21:38,500
what we call spectral energy

490
00:21:36,730 --> 00:21:41,140
distributions so this is sort of the

491
00:21:38,500 --> 00:21:44,109
energy or flux coming out of the galaxy

492
00:21:41,140 --> 00:21:45,910
on the y-axis and on the x-axis we have

493
00:21:44,109 --> 00:21:47,829
the wavelength in microns because

494
00:21:45,910 --> 00:21:53,440
infrared astronomers like myself like to

495
00:21:47,829 --> 00:21:55,480
think about microns this is ten a

496
00:21:53,440 --> 00:21:58,240
hundred a thousand and then kind of

497
00:21:55,480 --> 00:22:01,720
shaded in here is the range over which

498
00:21:58,240 --> 00:22:04,359
the Spitzer Space Observatory covered so

499
00:22:01,720 --> 00:22:06,039

it goes all the way from there to there

500
00:22:04,359 --> 00:22:08,349
and Hershel covers from here to there

501
00:22:06,039 --> 00:22:11,200
and so together you actually get the

502
00:22:08,349 --> 00:22:13,089
whole thing yeah if you get a little bit

503
00:22:11,200 --> 00:22:15,759
of the stars but the whole thing about

504
00:22:13,089 --> 00:22:18,279
the dust you get the warm dust with

505
00:22:15,759 --> 00:22:19,750
Spitzer with Herschel you get the colder

506
00:22:18,279 --> 00:22:21,639
dust you get the whole complete picture

507
00:22:19,750 --> 00:22:23,500
with it and what I'm going to talk to

508
00:22:21,640 --> 00:22:26,650
you about is the complete picture that

509
00:22:23,500 --> 00:22:31,298
we're learning from these these

510
00:22:26,650 --> 00:22:32,920
observations so this this image here I

511
00:22:31,298 --> 00:22:36,129
like this image because it kind of shows

512
00:22:32,920 --> 00:22:39,009
that whole lot dust lifecycle with the

513
00:22:36,130 --> 00:22:41,350
three colors so this is from Spitzer

514
00:22:39,009 --> 00:22:44,740
sage of the Large Magellanic Cloud and

515
00:22:41,349 --> 00:22:47,319
in purple here this is from the Spitzer

516
00:22:44,740 --> 00:22:49,269
Iraq camera at three point six microns

517
00:22:47,319 --> 00:22:51,819
and you can see all this blue here you

518
00:22:49,269 --> 00:22:53,679
can see kind of a faint glow of a bar

519
00:22:51,819 --> 00:22:57,129
and if you look in the optical the bar

520
00:22:53,679 --> 00:22:59,559
is very prominent but here it's it's a

521
00:22:57,130 --> 00:23:03,309
little fainter compared to the other

522
00:22:59,558 --> 00:23:05,829
dust things but here what we're tracing

523
00:23:03,308 --> 00:23:08,349
here is what I call the old stellar

524
00:23:05,829 --> 00:23:10,058
population the the old and dying stars

525
00:23:08,349 --> 00:23:13,000
and these are the stars remember that

526
00:23:10,058 --> 00:23:16,178
are producing the origin of dust so this

527
00:23:13,000 --> 00:23:18,669
blue glow here is sort of where lots of

528
00:23:16,179 --> 00:23:21,970
dust is originating from and then in

529
00:23:18,669 --> 00:23:24,190
green is sort of a tracer of the dust in

530
00:23:21,970 --> 00:23:27,370
the interstellar medium itself so that's

531
00:23:24,190 --> 00:23:30,700
the is M processing growth destruction

532
00:23:27,369 --> 00:23:33,819
that's the I rec eat micron emission and

533
00:23:30,700 --> 00:23:36,039
then in bright red here this is this

534
00:23:33,819 --> 00:23:38,980
MEPs 24 micron camera that's picks up

535
00:23:36,039 --> 00:23:40,990
sort of hot spots where massive stars

536
00:23:38,980 --> 00:23:43,210
are being formed in this galaxy and so

537
00:23:40,990 --> 00:23:48,190
this is one image kind of shows this

538
00:23:43,210 --> 00:23:49,720
whole life cycle now just to show you a

539
00:23:48,190 --> 00:23:51,640
compliment I'm going to be showing

540
00:23:49,720 --> 00:23:53,470
pictures of the SMC and the ellison this

541
00:23:51,640 --> 00:23:56,230
is the small magellanic cloud this is

542

00:23:53,470 --> 00:23:58,620
the Herschel heritage image and and

543
00:23:56,230 --> 00:24:00,819
Herschel remember all we're seeing is

544
00:23:58,619 --> 00:24:02,409
sort of dust emission from the

545
00:24:00,819 --> 00:24:05,139
interstellar medium that second pump

546
00:24:02,410 --> 00:24:06,790
it's all interstellar medium dust and

547
00:24:05,140 --> 00:24:09,759
you can see some brighter spots sort of

548
00:24:06,789 --> 00:24:14,440
where the dust is warmer redder spots

549
00:24:09,759 --> 00:24:17,109
were it's it's cooler all right so let's

550
00:24:14,440 --> 00:24:18,230
go back to our problem at him about why

551
00:24:17,109 --> 00:24:21,349
do galaxies have

552
00:24:18,230 --> 00:24:24,200
dust so this is first of all I we might

553
00:24:21,349 --> 00:24:25,879
we ask the question and how much dust

554
00:24:24,200 --> 00:24:28,069
are we talking about I mean how much do

555
00:24:25,880 --> 00:24:31,270
we actually need to keep there per

556
00:24:28,069 --> 00:24:35,450

galaxies to have dust well in the LMC

557
00:24:31,269 --> 00:24:37,700
it's 7.3 times plus or minus 1 times 10

558
00:24:35,450 --> 00:24:40,789
to the 5 solar masses of dust over the

559
00:24:37,700 --> 00:24:42,740
whole galaxy so that's how much dust is

560
00:24:40,789 --> 00:24:44,750
in this galaxy and this life cycle in

561
00:24:42,740 --> 00:24:47,809
some sense has to maintain our balance

562
00:24:44,750 --> 00:24:51,349
to keep it and in a small Magellanic

563
00:24:47,809 --> 00:24:53,720
Cloud it's less everything is smaller in

564
00:24:51,349 --> 00:24:55,699
the small Magellanic Cloud it's 8.3 plus

565
00:24:53,720 --> 00:24:58,069
minus one times 10 to the 4 so it's

566
00:24:55,700 --> 00:24:59,750
about a factor of 10 and everything

567
00:24:58,069 --> 00:25:02,899
about the small Magellanic Clouds about

568
00:24:59,750 --> 00:25:06,200
a factor of 10 smaller than the Large

569
00:25:02,900 --> 00:25:09,050
Magellanic Cloud all right let's go back

570
00:25:06,200 --> 00:25:11,569
to this life cycle of deaths and I want

571
00:25:09,049 --> 00:25:13,519
to show you what we've learned from

572
00:25:11,569 --> 00:25:15,679
these from these surveys over the past

573
00:25:13,519 --> 00:25:20,089
gosh almost 10 years I started this

574
00:25:15,680 --> 00:25:23,509
about 10 years ago and first we're gonna

575
00:25:20,089 --> 00:25:25,159
start off with the origin of dust so

576
00:25:23,509 --> 00:25:27,379
where does this come from what have we

577
00:25:25,160 --> 00:25:31,340
learn from these surveys that tell us

578
00:25:27,380 --> 00:25:33,980
about how dust is produced and polluting

579
00:25:31,339 --> 00:25:35,959
the galaxies so first I'm going to talk

580
00:25:33,980 --> 00:25:38,390
about asymptotic giant branch stores eg

581
00:25:35,960 --> 00:25:40,160
B stars and this is my favorite picture

582
00:25:38,390 --> 00:25:41,810
of an Ag bestir it's actually from one

583
00:25:40,160 --> 00:25:44,090
of the hottest new observatories the

584
00:25:41,809 --> 00:25:47,329
Alma Observatory the radio Observatory

585
00:25:44,089 --> 00:25:49,849
in the southern hemisphere in Chile and

586
00:25:47,329 --> 00:25:51,529
it just shows it looks kind of circular

587
00:25:49,849 --> 00:25:54,980
but there's also a spiral pattern and

588
00:25:51,529 --> 00:25:59,119
it's just puffing out the dust I'm along

589
00:25:54,980 --> 00:26:01,519
with molecular gas in this star in

590
00:25:59,119 --> 00:26:04,909
addition to the egb stars a more massive

591
00:26:01,519 --> 00:26:07,400
star things that go boom and explode is

592
00:26:04,910 --> 00:26:11,060
a red supergiant and this is a Hubble

593
00:26:07,400 --> 00:26:14,210
image of V Y Canis Majoris showing sort

594
00:26:11,059 --> 00:26:16,159
of the heart of it in reflected and all

595
00:26:14,210 --> 00:26:17,990
this light here is basically starlight

596
00:26:16,160 --> 00:26:23,600
reflected in the dust by the dust

597
00:26:17,990 --> 00:26:27,559
surrounding this star alright so in the

598
00:26:23,599 --> 00:26:30,289
large LMC and small Magellanic Cloud we

599

00:26:27,559 --> 00:26:33,740
had to identify which of the stars are

600
00:26:30,289 --> 00:26:35,869
actually dust producers and we do that

601
00:26:33,740 --> 00:26:38,450
using these diagrams called

602
00:26:35,869 --> 00:26:40,849
color-magnitude diagram and so what this

603
00:26:38,450 --> 00:26:44,210
is is we measure the flux every star in

604
00:26:40,849 --> 00:26:48,889
the galaxy and then we plot that flux

605
00:26:44,210 --> 00:26:50,900
used this system astronomer system

606
00:26:48,890 --> 00:26:54,860
called magnitudes and so this is 8

607
00:26:50,900 --> 00:26:57,410
micron emission in magnitudes and this

608
00:26:54,859 --> 00:26:59,839
is the color so this is j-man so this is

609
00:26:57,410 --> 00:27:01,490
about 1 micron minus 8 microns and so as

610
00:26:59,839 --> 00:27:04,609
you go to the right you're getting to a

611
00:27:01,490 --> 00:27:06,470
redder and redder star and as you go up

612
00:27:04,609 --> 00:27:11,179
I'm you're getting to a brighter

613
00:27:06,470 --> 00:27:13,970

brighter star and the pattern of this

614
00:27:11,180 --> 00:27:16,970
contour is sort of the location a sort

615
00:27:13,970 --> 00:27:18,829
of a density plot of all the stars in

616
00:27:16,970 --> 00:27:20,420
these respective galaxies and what we've

617
00:27:18,829 --> 00:27:22,369
identified here there are all sorts of

618
00:27:20,420 --> 00:27:24,560
features there structure in this contour

619
00:27:22,369 --> 00:27:27,919
plot and that structure is actually

620
00:27:24,559 --> 00:27:30,980
different types and types of objects red

621
00:27:27,920 --> 00:27:34,190
supergiant I'm sorry red supergiant's

622
00:27:30,980 --> 00:27:35,839
and the egb stars are there in that but

623
00:27:34,190 --> 00:27:38,210
there's a lot of other things and so the

624
00:27:35,839 --> 00:27:40,549
first tack job is to find out and

625
00:27:38,210 --> 00:27:45,370
identify those sources that are the AGB

626
00:27:40,549 --> 00:27:47,720
stars in the red supergiant's and then

627
00:27:45,369 --> 00:27:49,579
and then you have to sort of model how

628
00:27:47,720 --> 00:27:53,150
much dust is around them and for that

629
00:27:49,579 --> 00:27:55,009
because we have all the measurements for

630
00:27:53,150 --> 00:27:57,080
the dust is we can again create a

631
00:27:55,009 --> 00:28:00,440
spectral energy distribution for every

632
00:27:57,079 --> 00:28:02,599
star in the galaxy every AGB star again

633
00:28:00,440 --> 00:28:04,730
this is how much flux or energy that's

634
00:28:02,599 --> 00:28:08,779
coming out versus wavelength there's 1

635
00:28:04,730 --> 00:28:11,120
to 10 microns and this is a case of a an

636
00:28:08,779 --> 00:28:14,529
oxygen-rich source and how do we know

637
00:28:11,119 --> 00:28:18,679
it's oxygen-rich we look at its spectrum

638
00:28:14,529 --> 00:28:21,799
and what we've I call this thing grams

639
00:28:18,680 --> 00:28:23,539
because to calculate all the dusts in

640
00:28:21,799 --> 00:28:25,490
all these stars there were a lot of

641
00:28:23,539 --> 00:28:28,159
stars there like tens of thousands of

642
00:28:25,490 --> 00:28:29,779
them so we created a grid of red

643
00:28:28,160 --> 00:28:32,540
supergiant asymptotic giant branch

644
00:28:29,779 --> 00:28:36,079
models we call them grams because we

645
00:28:32,539 --> 00:28:38,420
were weighing to dust and we use this

646
00:28:36,079 --> 00:28:40,939
particular source to figure out the type

647
00:28:38,420 --> 00:28:43,090
of dust and so this spectrum there's a

648
00:28:40,940 --> 00:28:47,259
little feature here and there and this

649
00:28:43,089 --> 00:28:49,000
indicative of silicates in the star so

650
00:28:47,259 --> 00:28:50,529
you can take a spectrum of silicates

651
00:28:49,000 --> 00:28:52,000
turn around galaxy you would see the

652
00:28:50,529 --> 00:28:53,529
same it's already in our own

653
00:28:52,000 --> 00:28:55,390
laboratories and you see these features

654
00:28:53,529 --> 00:29:00,250
and so we know it's silicates from the

655
00:28:55,390 --> 00:29:03,250
spectrum and then we model the energy in

656

00:29:00,250 --> 00:29:05,980
silicates here and from that modeling we

657
00:29:03,250 --> 00:29:08,529
can determine the luminosity of the star

658
00:29:05,980 --> 00:29:10,690
and what we call a dust mask loss rate

659
00:29:08,529 --> 00:29:12,369
and so this is the luminosity so it's

660
00:29:10,690 --> 00:29:14,200
five thousand eighty eight times the

661
00:29:12,369 --> 00:29:16,389
luminosity of our Sun it's much much

662
00:29:14,200 --> 00:29:19,900
more luminous than our Sun and our Sun

663
00:29:16,390 --> 00:29:22,420
will get this luminous when it dies and

664
00:29:19,900 --> 00:29:24,820
then this is the amount of dust it's

665
00:29:22,420 --> 00:29:28,870
producing per year this one star two

666
00:29:24,819 --> 00:29:29,200
times ten to the minus nine per year all

667
00:29:28,869 --> 00:29:32,319
right

668
00:29:29,200 --> 00:29:34,450
so that was the very nitrogen rich start

669
00:29:32,319 --> 00:29:37,089
where does carbon dust come from things

670
00:29:34,450 --> 00:29:40,360

like polycyclic aromatic hydrocarbons

671
00:29:37,089 --> 00:29:42,459
and carbonaceous dust and soot that

672
00:29:40,359 --> 00:29:45,789
comes from things called carbon stars

673
00:29:42,460 --> 00:29:47,980
and a carbon star again is an asymptotic

674
00:29:45,789 --> 00:29:51,159
giant branch star in which the innards

675
00:29:47,980 --> 00:29:53,019
of the star has turned out enough to

676
00:29:51,160 --> 00:29:54,970
change the chemistry on the surface of

677
00:29:53,019 --> 00:29:56,950
the star from oxygen-rich which is

678
00:29:54,970 --> 00:30:00,250
pretty much what the universe is to

679
00:29:56,950 --> 00:30:02,319
something carbonaceous and we know that

680
00:30:00,250 --> 00:30:04,269
these stars have carbonaceous dust

681
00:30:02,319 --> 00:30:05,919
because they're mostly features except

682
00:30:04,269 --> 00:30:09,670
there's a little feature here from a

683
00:30:05,920 --> 00:30:12,580
silicon carbide feature si si and so

684
00:30:09,670 --> 00:30:15,550
again we used grams and we modeled what

685
00:30:12,579 --> 00:30:18,699
is coming from the star with a spectral

686
00:30:15,549 --> 00:30:20,559
energy distribution and we find out that

687
00:30:18,700 --> 00:30:23,259
it's also over five thousand solar

688
00:30:20,559 --> 00:30:26,519
luminosities and it's about 2.6 times

689
00:30:23,259 --> 00:30:29,170
minus nine solar masses of dust per year

690
00:30:26,519 --> 00:30:31,990
all right so those are two example stars

691
00:30:29,170 --> 00:30:36,670
and the types of dust that we get from

692
00:30:31,990 --> 00:30:38,769
them but again we have like thousands

693
00:30:36,670 --> 00:30:41,380
tens of thousands 30 thousands of these

694
00:30:38,769 --> 00:30:44,019
stars and so what we did was we created

695
00:30:41,380 --> 00:30:46,060
this grid and this is a representation

696
00:30:44,019 --> 00:30:50,069
of the grid on a color magnitude diagram

697
00:30:46,059 --> 00:30:53,230
of the eight versus three point six

698
00:30:50,069 --> 00:30:56,299
minus eight and in grayer all the models

699
00:30:53,230 --> 00:30:57,920
we created and then in blue

700
00:30:56,299 --> 00:31:00,829
are all the sources in the large

701
00:30:57,920 --> 00:31:04,580
magellanic cloud so blue is where all

702
00:31:00,829 --> 00:31:07,009
the LMC oxygen-rich sources are and in

703
00:31:04,579 --> 00:31:09,289
red are the carbon rich sources because

704
00:31:07,009 --> 00:31:14,240
there's two types of dust carbonaceous

705
00:31:09,289 --> 00:31:19,759
and silica based dust and they all go

706
00:31:14,240 --> 00:31:21,200
out all right so what are the things

707
00:31:19,759 --> 00:31:25,160
that we've learned about these stars

708
00:31:21,200 --> 00:31:27,380
well I mentioned the oxygen rich sources

709
00:31:25,160 --> 00:31:30,140
the carbon rich sources and then this

710
00:31:27,380 --> 00:31:32,800
shows in some sense the luminosity

711
00:31:30,140 --> 00:31:35,450
function I was telling you that we have

712
00:31:32,799 --> 00:31:37,039
sources that are 5000 solar luminosities

713

00:31:35,450 --> 00:31:41,960
we have some that are even greater than

714
00:31:37,039 --> 00:31:44,960
that so in the purple the blue here is

715
00:31:41,960 --> 00:31:47,390
the oxygen rich sources and the solid

716
00:31:44,960 --> 00:31:50,480
line the SMC it's been scaled up but

717
00:31:47,390 --> 00:31:54,140
that's for the SMC and again for the LMC

718
00:31:50,480 --> 00:31:56,000
we have the red solid line for the

719
00:31:54,140 --> 00:31:58,070
carbon sources and the dashed line for

720
00:31:56,000 --> 00:32:00,319
thee for the SMC and then what I've

721
00:31:58,069 --> 00:32:03,799
shown here is sort of a it's a dashed

722
00:32:00,319 --> 00:32:05,419
line of the separating what we call the

723
00:32:03,799 --> 00:32:08,389
eg B or the asymptotic giant branch

724
00:32:05,420 --> 00:32:11,720
stars from the red supergiant's and this

725
00:32:08,390 --> 00:32:13,460
is important because these types of

726
00:32:11,720 --> 00:32:15,079
stars on the right are the stars that

727
00:32:13,460 --> 00:32:17,539

explode as supernovae those are the

728
00:32:15,079 --> 00:32:22,220
massive stars that explode whereas those

729
00:32:17,539 --> 00:32:25,519
on the left are the ones that are going

730
00:32:22,220 --> 00:32:28,130
to die quietly like like white dwarfs

731
00:32:25,519 --> 00:32:29,809
and planetary nebulae and one point I

732
00:32:28,130 --> 00:32:34,130
want to make here is that you can see

733
00:32:29,809 --> 00:32:36,379
that the carbonaceous winds only come

734
00:32:34,130 --> 00:32:39,890
from the AGB stars red supergiant's

735
00:32:36,380 --> 00:32:42,140
don't turn up carbon so a lot of people

736
00:32:39,890 --> 00:32:44,690
think a lot of the carbonaceous dust in

737
00:32:42,140 --> 00:32:50,360
the universe comes from stars like our

738
00:32:44,690 --> 00:32:52,759
Sun when they die alright so we've

739
00:32:50,359 --> 00:32:54,559
applied these grams models through all

740
00:32:52,759 --> 00:32:56,660
the populations in the Large Magellanic

741
00:32:54,559 --> 00:32:58,250
Cloud and Small Magellanic Cloud and it

742
00:32:56,660 --> 00:33:02,450
said okay well how much dust are we

743
00:32:58,250 --> 00:33:04,640
producing so this is what on the y axis

744
00:33:02,450 --> 00:33:07,759
we call cumulative dust production rate

745
00:33:04,640 --> 00:33:09,860
in solar masses per year so this is ten

746
00:33:07,759 --> 00:33:14,179
the minus five solar masses

747
00:33:09,859 --> 00:33:17,659
- six and what I show here in the black

748
00:33:14,179 --> 00:33:21,410
are all the sources in the LMC red is

749
00:33:17,660 --> 00:33:24,110
again carbon sources blue it's oxygen

750
00:33:21,410 --> 00:33:26,990
rich sources and again you can see the

751
00:33:24,109 --> 00:33:30,709
SMC is smaller than the LMC by a factor

752
00:33:26,990 --> 00:33:32,539
of 10 just to show you what some of the

753
00:33:30,710 --> 00:33:35,298
numbers are concrete ly so there have

754
00:33:32,539 --> 00:33:38,569
been a couple of papers by former

755
00:33:35,298 --> 00:33:40,910
students of mine one by RIBA where he

756
00:33:38,569 --> 00:33:43,579
says the total dust produced in the LMC

757
00:33:40,910 --> 00:33:45,919
now by these stars the stellar winds is

758
00:33:43,579 --> 00:33:49,808
2.1 times in the mines five solar masses

759
00:33:45,919 --> 00:33:53,120
per year it's quite a lot and the SMC

760
00:33:49,808 --> 00:33:55,220
it's about eight point nine times ten to

761
00:33:53,119 --> 00:33:58,879
the minus seven solar masses per year

762
00:33:55,220 --> 00:34:02,029
and then what is the breakdown so in the

763
00:33:58,880 --> 00:34:04,100
LMC it seems to be dominated by carbon

764
00:34:02,029 --> 00:34:05,899
rich dust production so we have more

765
00:34:04,099 --> 00:34:09,199
carbon rich dust being produced by these

766
00:34:05,900 --> 00:34:14,090
stars than the oxygen rich dust and the

767
00:34:09,199 --> 00:34:15,918
S&C it seems to be more 5050 and then

768
00:34:14,090 --> 00:34:18,710
when you look at the oxygen rich dusts

769
00:34:15,918 --> 00:34:20,690
remember you can have sort of the lower

770

00:34:18,710 --> 00:34:24,320
mass stars like the AGB stars in the red

771
00:34:20,690 --> 00:34:27,829
supergiant's so the red supergiant's

772
00:34:24,320 --> 00:34:29,750
it's only about 9% in the LMC and the

773
00:34:27,829 --> 00:34:34,668
SMC it seems to be about half and half

774
00:34:29,750 --> 00:34:36,168
25% red supergiant 25% a GB so you kind

775
00:34:34,668 --> 00:34:38,210
of look at the red supergiant scene

776
00:34:36,168 --> 00:34:39,710
you're thinking well the massive stars

777
00:34:38,210 --> 00:34:41,539
really aren't doing very much it seems

778
00:34:39,710 --> 00:34:45,490
to be all these kind of lower mass solar

779
00:34:41,539 --> 00:34:45,489
mass stars doing most of the work and

780
00:34:45,789 --> 00:34:52,608
okay this is okay but the truth is maybe

781
00:34:50,358 --> 00:34:56,000
things happen later in the massive

782
00:34:52,608 --> 00:34:58,400
star's life and it turns out that as the

783
00:34:56,000 --> 00:35:01,460
massive star gets closer to death it has

784
00:34:58,400 --> 00:35:03,349

more phases than the lower mass stars so

785
00:35:01,460 --> 00:35:04,849
this for example is what's called a

786
00:35:03,349 --> 00:35:07,219
luminous blue variable and this is the

787
00:35:04,849 --> 00:35:10,279
iconic one from the Hubble image of a to

788
00:35:07,219 --> 00:35:12,169
Carina this is not in the LMC but there

789
00:35:10,280 --> 00:35:14,780
are objects like that in the LMC and

790
00:35:12,170 --> 00:35:17,470
this is one of the more famous luminous

791
00:35:14,780 --> 00:35:20,030
blue variable objects r71

792
00:35:17,469 --> 00:35:22,129
it has a dust mask of eight times to the

793
00:35:20,030 --> 00:35:23,510
minus seven solar masses per year and

794
00:35:22,130 --> 00:35:26,539
there are five

795
00:35:23,510 --> 00:35:28,340
BB's in the SMC and it's possible that

796
00:35:26,539 --> 00:35:30,440
if all of them each of them have that

797
00:35:28,340 --> 00:35:32,930
much dust production you actually get a

798
00:35:30,440 --> 00:35:35,030
pretty hefty amount of dust coming from

799
00:35:32,929 --> 00:35:39,349
these lb B's four times ten minus six

800
00:35:35,030 --> 00:35:43,370
solar masses per year but you know it

801
00:35:39,349 --> 00:35:48,639
turns out that see if I can get this to

802
00:35:43,369 --> 00:35:48,639
go oh there we go

803
00:35:52,849 --> 00:35:59,539
here we go turns out that the mass of

804
00:35:55,818 --> 00:36:03,679
stars really do produce a lot of dust

805
00:35:59,539 --> 00:36:09,970
and when it happens those at the very

806
00:36:03,679 --> 00:36:09,969
very end of its life when it explodes

807
00:36:18,900 --> 00:36:26,400
so Frank's talk about the heart of the

808
00:36:22,380 --> 00:36:28,470
Crab Nebula this is sort of a movie

809
00:36:26,400 --> 00:36:30,389
version of how that Crab Nebula was was

810
00:36:28,469 --> 00:36:34,049
created it's basically a star exploding

811
00:36:30,389 --> 00:36:37,589
in and dying and one of the largest

812
00:36:34,050 --> 00:36:39,720
surprises for us in the Magellanic Cloud

813
00:36:37,590 --> 00:36:43,590
search was that we actually detected

814
00:36:39,719 --> 00:36:45,839
dustin87 a it was pretty much a

815
00:36:43,590 --> 00:36:48,329
discovery I mean in it that people are

816
00:36:45,840 --> 00:36:51,780
rapidly following up on so this is

817
00:36:48,329 --> 00:36:53,909
supernova 1987a this is a Hubble image

818
00:36:51,780 --> 00:36:58,170
of it it's still the manager by Hubble

819
00:36:53,909 --> 00:37:01,739
and it Hubble launched shortly after you

820
00:36:58,170 --> 00:37:04,590
know this thing exploded and this is a

821
00:37:01,739 --> 00:37:06,599
picture of the field and Hubble and this

822
00:37:04,590 --> 00:37:10,860
is a picture of our Herschel heritage

823
00:37:06,599 --> 00:37:13,170
image and we found it and I remember the

824
00:37:10,860 --> 00:37:15,150
phone conversation when we were trying

825
00:37:13,170 --> 00:37:17,730
to pick follow-up sources of supernova

826
00:37:15,150 --> 00:37:19,619
remnants to follow up on with the

827

00:37:17,730 --> 00:37:22,260
spectroscopy capability of Herschel and

828
00:37:19,619 --> 00:37:26,369
a postdoc was going through and she says

829
00:37:22,260 --> 00:37:28,320
oh we have and 49 that's like yeah ok n

830
00:37:26,369 --> 00:37:30,630
1 3 2 is like ok that's exciting and we

831
00:37:28,320 --> 00:37:32,250
have 87 I said well hold it there we

832
00:37:30,630 --> 00:37:34,349
don't have 87 me we're not supposed to

833
00:37:32,250 --> 00:37:36,960
see it she says well I'm sorry but we

834
00:37:34,349 --> 00:37:42,150
see it and I was like ok well that's

835
00:37:36,960 --> 00:37:44,190
very very interesting and the

836
00:37:42,150 --> 00:37:48,119
interesting thing about it is here we

837
00:37:44,190 --> 00:37:50,670
have a close-up of 87a here's the ring

838
00:37:48,119 --> 00:37:51,900
this ring was created by the prior

839
00:37:50,670 --> 00:37:53,610
remember I was talking about the stellar

840
00:37:51,900 --> 00:37:55,530
winds and the red supergiant's creating

841
00:37:53,610 --> 00:37:58,940

those winds that material drifts out

842
00:37:55,530 --> 00:38:02,610
that's what the ring is it's that prior

843
00:37:58,940 --> 00:38:05,070
progenitor star wind and at the heart of

844
00:38:02,610 --> 00:38:08,340
it is the ejecta so this is the exploded

845
00:38:05,070 --> 00:38:10,620
star and this is the star from the prior

846
00:38:08,340 --> 00:38:16,140
wind and here it is in x-rays as well

847
00:38:10,619 --> 00:38:20,009
and when we were proposing to observe

848
00:38:16,139 --> 00:38:21,690
the LMC with Herschel we said well can

849
00:38:20,010 --> 00:38:23,250
we see 80 70 because it's such a famous

850
00:38:21,690 --> 00:38:25,260
object if we can see it we should tell

851
00:38:23,250 --> 00:38:27,480
them we're gonna see it and at the time

852
00:38:25,260 --> 00:38:29,310
this is what we knew ok well here is you

853
00:38:27,480 --> 00:38:31,409
know here's what we got with spitzer and

854
00:38:29,309 --> 00:38:32,079
spitzer went up and then up Spitzer's

855
00:38:31,409 --> 00:38:35,210
came down

856
00:38:32,079 --> 00:38:37,069
and so we said well you follow this line

857
00:38:35,210 --> 00:38:38,480
down again this is one of these spectral

858
00:38:37,070 --> 00:38:41,000
energy distribution where you have the

859
00:38:38,480 --> 00:38:42,650
amount of energy and wavelength and you

860
00:38:41,000 --> 00:38:44,449
keep going down and well here's where

861
00:38:42,650 --> 00:38:46,820
Herschel started and we were on this

862
00:38:44,449 --> 00:38:49,460
yellow I was like there is no way we're

863
00:38:46,820 --> 00:38:51,650
going to detect this object and so when

864
00:38:49,460 --> 00:38:55,099
we detected it we're like wow what is

865
00:38:51,650 --> 00:38:57,380
this and so what it is is you can see

866
00:38:55,099 --> 00:39:01,119
sort of two peaks of dust the ring dust

867
00:38:57,380 --> 00:39:04,280
we said this has got to be in the ejecta

868
00:39:01,119 --> 00:39:07,549
with it the ejecta really well you know

869
00:39:04,280 --> 00:39:10,690
how much dust would you need to create

870
00:39:07,550 --> 00:39:14,570
this much emission in the floor infrared

871
00:39:10,690 --> 00:39:16,429
and it turns out it's about 0.4 to 0.7

872
00:39:14,570 --> 00:39:18,200
solar masses of dust and there's a large

873
00:39:16,429 --> 00:39:20,659
uncertainty because we don't know the

874
00:39:18,199 --> 00:39:22,399
composition of this dust yet that's

875
00:39:20,659 --> 00:39:25,369
actually something I hope to tackle with

876
00:39:22,400 --> 00:39:27,740
James Webb that's a lot of dust I mean

877
00:39:25,369 --> 00:39:29,569
no one has ever seen that much dust in a

878
00:39:27,739 --> 00:39:31,159
supernova remnant before most of the

879
00:39:29,570 --> 00:39:33,410
dust people see is like 10 to minus

880
00:39:31,159 --> 00:39:35,029
three solar masses of dust from prior

881
00:39:33,409 --> 00:39:38,239
measurements so this was really really

882
00:39:35,030 --> 00:39:40,190
quite remarkable and we published it in

883
00:39:38,239 --> 00:39:42,439
science and people got all excited but

884

00:39:40,190 --> 00:39:44,240
they kind of said look you know you got

885
00:39:42,440 --> 00:39:46,789
some kind of fluff there you really you

886
00:39:44,239 --> 00:39:48,709
know you don't have the resolution you

887
00:39:46,789 --> 00:39:51,199
know I don't think it's I don't think

888
00:39:48,710 --> 00:39:52,730
it's a supernova you're like okay okay

889
00:39:51,199 --> 00:39:55,129
we're gonna go look at it with this hot

890
00:39:52,730 --> 00:39:58,699
new telescope called Alma and we're

891
00:39:55,130 --> 00:40:01,460
gonna measure from the ring emission to

892
00:39:58,699 --> 00:40:03,679
dust and see if it's there we think it's

893
00:40:01,460 --> 00:40:06,769
going to be there so but they got the

894
00:40:03,679 --> 00:40:08,480
time and this is what it looked like

895
00:40:06,769 --> 00:40:10,730
going it from these longer wavelengths

896
00:40:08,480 --> 00:40:12,980
so this is really trust testing they

897
00:40:10,730 --> 00:40:16,519
were finding the ring emission there's a

898
00:40:12,980 --> 00:40:20,570

lot of synchrotron emission and then as

899
00:40:16,519 --> 00:40:22,489
you go to the shorter wavelengths you

900
00:40:20,570 --> 00:40:24,800
get more into the dust emission you can

901
00:40:22,489 --> 00:40:26,419
see well there's a ring and hold it

902
00:40:24,800 --> 00:40:28,370
there's something in the center and when

903
00:40:26,420 --> 00:40:30,110
you go to the highest line it's in the

904
00:40:28,369 --> 00:40:31,730
center and so this very clearly it

905
00:40:30,110 --> 00:40:33,950
silenced all the critics they said oh

906
00:40:31,730 --> 00:40:35,840
yeah gosh you do have a lot of dust

907
00:40:33,949 --> 00:40:38,319
there and all the theorists are running

908
00:40:35,840 --> 00:40:42,110
madly around trying to figure out why

909
00:40:38,320 --> 00:40:44,450
all right so that's the story of of dust

910
00:40:42,110 --> 00:40:45,710
of dust production so let's talk a

911
00:40:44,449 --> 00:40:47,539
little bit about

912
00:40:45,710 --> 00:40:51,710
what happens when these dust grains go

913
00:40:47,539 --> 00:40:54,380
out into the interstellar medium all

914
00:40:51,710 --> 00:40:57,858
right so here's a supernova remnant in

915
00:40:54,380 --> 00:41:00,769
the Large Magellanic Cloud and 49 this

916
00:40:57,858 --> 00:41:03,319
is a beautiful composite HST glorious

917
00:41:00,769 --> 00:41:08,358
detail with Chandra in the blue because

918
00:41:03,320 --> 00:41:10,670
it's a hot plasma and so because of the

919
00:41:08,358 --> 00:41:12,079
87 a discovery there's a student at

920
00:41:10,670 --> 00:41:13,608
Keele what she said well I'm gonna look

921
00:41:12,079 --> 00:41:15,230
around at all the supernova remnants to

922
00:41:13,608 --> 00:41:18,289
see if they have dust in them and so she

923
00:41:15,230 --> 00:41:20,059
looked and here's n 49 and these plots

924
00:41:18,289 --> 00:41:24,289
these color plots I'm showing you here

925
00:41:20,059 --> 00:41:27,289
is her study showing on the left here

926
00:41:24,289 --> 00:41:28,608
this is dust mass and on the right this

927
00:41:27,289 --> 00:41:31,880
is dust temperature so it's like a

928
00:41:28,608 --> 00:41:37,039
little map around and 49 which is in the

929
00:41:31,880 --> 00:41:37,900
circle here and on the top is cold sort

930
00:41:37,039 --> 00:41:40,579
of cold dust

931
00:41:37,900 --> 00:41:44,300
this is warm dust those two components

932
00:41:40,579 --> 00:41:45,980
she she modeled and so here at the

933
00:41:44,300 --> 00:41:48,320
center you can see that well on coal

934
00:41:45,980 --> 00:41:51,679
dust there's doesn't really seem to be

935
00:41:48,320 --> 00:41:56,720
much there there seems to be some warm

936
00:41:51,679 --> 00:42:00,759
dust some mass and warm dust and and

937
00:41:56,719 --> 00:42:02,989
here again this is cold and this is warm

938
00:42:00,760 --> 00:42:04,640
but really when she looked at all the

939
00:42:02,989 --> 00:42:06,618
whole samples she really did not find

940
00:42:04,639 --> 00:42:09,409
much dust at the center of these things

941

00:42:06,619 --> 00:42:12,289
and some of that is could be a limit to

942
00:42:09,409 --> 00:42:15,019
the sensitivity for Herschel and mostly

943
00:42:12,289 --> 00:42:18,259
what she measured then was what happened

944
00:42:15,019 --> 00:42:20,150
to the surrounding part and she found

945
00:42:18,260 --> 00:42:21,589
that really well gosh these supernovae

946
00:42:20,150 --> 00:42:23,570
room knows as they go out they're really

947
00:42:21,588 --> 00:42:26,358
destroying the dust and so her paper

948
00:42:23,570 --> 00:42:29,330
showed that there's some dust

949
00:42:26,358 --> 00:42:31,338
destruction and then we did a slightly

950
00:42:29,329 --> 00:42:33,108
more rigorous calculation on the

951
00:42:31,338 --> 00:42:35,059
supernova remnants in large magellanic

952
00:42:33,108 --> 00:42:43,329
cloud here's all of them in the in the

953
00:42:35,059 --> 00:42:46,039
red circles and this is sort of the

954
00:42:43,329 --> 00:42:47,509
amount of dust that's destroyed by them

955
00:42:46,039 --> 00:42:50,300

so this is the number of supernova

956
00:42:47,510 --> 00:42:52,040
remnants and this is how effectively

957
00:42:50,300 --> 00:42:53,869
they are destroying the carbonaceous

958
00:42:52,039 --> 00:42:55,739
stuff in the interstellar medium or the

959
00:42:53,869 --> 00:42:57,510
silicate dust and

960
00:42:55,739 --> 00:42:59,250
or seller medium you can see that the

961
00:42:57,510 --> 00:43:03,420
silica dust is actually more readily

962
00:42:59,250 --> 00:43:05,369
destroyed than the carbonaceous dust in

963
00:43:03,420 --> 00:43:07,440
fact you can kind of figure out what is

964
00:43:05,369 --> 00:43:09,180
the average lifetime for dust grains so

965
00:43:07,440 --> 00:43:10,559
these stars produce the dust and they

966
00:43:09,179 --> 00:43:13,440
kind of hover out in the interstellar

967
00:43:10,559 --> 00:43:16,230
medium how long can they possibly last

968
00:43:13,440 --> 00:43:18,659
given all these supernovae in them and

969
00:43:16,230 --> 00:43:21,690
remnant sweeping through so this is dust

970
00:43:18,659 --> 00:43:23,429
lifetime this is a parameter sort of how

971
00:43:21,690 --> 00:43:26,490
effective the LMC along the line of

972
00:43:23,429 --> 00:43:28,289
sight this is the LM seeing the SMC so

973
00:43:26,489 --> 00:43:29,939
to get a dust lifetime you say well how

974
00:43:28,289 --> 00:43:31,259
much is the total mass of dust and now

975
00:43:29,940 --> 00:43:32,639
there was the number I gave you at the

976
00:43:31,260 --> 00:43:34,980
beginning of this talk how much is the

977
00:43:32,639 --> 00:43:37,679
total mass in the in the galaxy of dust

978
00:43:34,980 --> 00:43:40,699
and then what is the average amount of

979
00:43:37,679 --> 00:43:42,480
dust destroyed per supernova remnant

980
00:43:40,699 --> 00:43:44,460
that comes from a theoretical

981
00:43:42,480 --> 00:43:46,108
calculation and then this is the rate of

982
00:43:44,460 --> 00:43:47,550
supernovae which is just sort of the

983
00:43:46,108 --> 00:43:51,299
rate at which stars are formed at a

984
00:43:47,550 --> 00:43:53,430
massive mess that can explode and when

985
00:43:51,300 --> 00:43:56,580
you get in the LMC is that well silica

986
00:43:53,429 --> 00:44:00,509
dust grains can only live 26 to 42

987
00:43:56,579 --> 00:44:04,319
million years really really short I mean

988
00:44:00,510 --> 00:44:11,099
remember how old is our Sun anyone know

989
00:44:04,320 --> 00:44:12,690
that billions five billion right and

990
00:44:11,099 --> 00:44:16,320
it's gonna get it's gonna get up to ten

991
00:44:12,690 --> 00:44:18,300
billion before it dies so here's 42

992
00:44:16,320 --> 00:44:23,160
million so a lot lot shorter than that

993
00:44:18,300 --> 00:44:26,760
than the lifetime of one of our stars so

994
00:44:23,159 --> 00:44:30,000
so dust is destroyed in the interstellar

995
00:44:26,760 --> 00:44:35,400
medium and the question is do we have

996
00:44:30,000 --> 00:44:38,608
any evidence that it grows back and here

997
00:44:35,400 --> 00:44:39,869
we've been looking at maps of dusty gas

998

00:44:38,608 --> 00:44:41,819
eration so we're using the Herschel

999
00:44:39,869 --> 00:44:44,220
images or figuring and we get a total

1000
00:44:41,820 --> 00:44:46,650
map of the dust I showed you that at the

1001
00:44:44,219 --> 00:44:47,879
beginning and my colleague Julie Roman

1002
00:44:46,650 --> 00:44:51,150
de balón said okay well I'm going to

1003
00:44:47,880 --> 00:44:56,250
compare it to the gas and look at how

1004
00:44:51,150 --> 00:44:58,440
the gas to dust ratio that's N and here

1005
00:44:56,250 --> 00:45:00,780
in the SMC in particular you can see

1006
00:44:58,440 --> 00:45:03,420
that here's here's a gas cloud that's

1007
00:45:00,780 --> 00:45:08,099
showed here in the contours and you can

1008
00:45:03,420 --> 00:45:09,210
see that the gas to dust ratio appears

1009
00:45:08,099 --> 00:45:12,829
to be

1010
00:45:09,210 --> 00:45:16,920
Louis that is the amount of gas per dust

1011
00:45:12,829 --> 00:45:20,160
is lower when you get to these gas

1012
00:45:16,920 --> 00:45:21,838

clouds so just to flip that around that

1013
00:45:20,159 --> 00:45:24,028
means there's more dust

1014
00:45:21,838 --> 00:45:29,190
apparently more dust in these clouds

1015
00:45:24,028 --> 00:45:30,929
than gas in these denser clouds so the

1016
00:45:29,190 --> 00:45:32,338
tricky thing is though that it's a hard

1017
00:45:30,929 --> 00:45:33,838
thing to prove with these measurements

1018
00:45:32,338 --> 00:45:35,639
because they're kind of course they're

1019
00:45:33,838 --> 00:45:37,619
the measurements are you know they're

1020
00:45:35,639 --> 00:45:40,318
factors of two or three and certainty

1021
00:45:37,619 --> 00:45:43,079
because we're using all these model fits

1022
00:45:40,318 --> 00:45:44,849
and stuff and so we said whoa Kay let's

1023
00:45:43,079 --> 00:45:48,960
use a more precise tool let's use

1024
00:45:44,849 --> 00:45:51,599
spectroscopy and so we another way of

1025
00:45:48,960 --> 00:45:53,730
studying what we're dust is is what we

1026
00:45:51,599 --> 00:45:56,519
call metal depletion onto dust grains so

1027
00:45:53,730 --> 00:45:58,170
what is dust made of so we you know we

1028
00:45:56,519 --> 00:46:00,028
kind of think of the dust bunnies on our

1029
00:45:58,170 --> 00:46:02,130
carpet but actually if you analyze those

1030
00:46:00,028 --> 00:46:04,949
maybe it would be similar but it's

1031
00:46:02,130 --> 00:46:07,289
basically anything that has metals so it

1032
00:46:04,949 --> 00:46:10,108
could be iron it could be carbon the

1033
00:46:07,289 --> 00:46:13,440
oxygen silicon all bound together in

1034
00:46:10,108 --> 00:46:15,210
these complex solid features so it's

1035
00:46:13,440 --> 00:46:20,880
made of metals these have things much

1036
00:46:15,210 --> 00:46:22,949
heavier than than helium and if you look

1037
00:46:20,880 --> 00:46:24,568
along the line of sight towards a star

1038
00:46:22,949 --> 00:46:28,139
you can look in reflection and you can

1039
00:46:24,568 --> 00:46:31,230
see how much how many metals are there

1040
00:46:28,139 --> 00:46:34,108
and you can compare it to what we know

1041
00:46:31,230 --> 00:46:36,389
should be there and then the depletion

1042
00:46:34,108 --> 00:46:41,130
is basically the metals that are missing

1043
00:46:36,389 --> 00:46:42,690
from the interstellar medium all right

1044
00:46:41,130 --> 00:46:44,789
so let me just walk you through this a

1045
00:46:42,690 --> 00:46:48,000
bit more so here's one of the stars we

1046
00:46:44,789 --> 00:46:49,799
looked at here's a spectrum from an

1047
00:46:48,000 --> 00:46:51,900
ultraviolet spectrum so these are

1048
00:46:49,798 --> 00:46:56,038
measurements taken with Hubble and with

1049
00:46:51,900 --> 00:46:59,608
the with fuse and it shows again here's

1050
00:46:56,039 --> 00:47:01,319
wavelengths and here's here's flexes and

1051
00:46:59,608 --> 00:47:04,170
you can see these dips here this is

1052
00:47:01,318 --> 00:47:07,230
absorption dips from gas and the

1053
00:47:04,170 --> 00:47:12,389
interstellar medium and its absorption

1054
00:47:07,230 --> 00:47:15,179
debts due to iron or silicon or thing

1055

00:47:12,389 --> 00:47:17,879
for magnesium or chromium and all these

1056
00:47:15,179 --> 00:47:21,480
are trace heavy metals that we use to

1057
00:47:17,880 --> 00:47:23,910
understand and trace where dust where

1058
00:47:21,480 --> 00:47:25,980
dust is forming

1059
00:47:23,909 --> 00:47:28,798
so we measured these for a number of

1060
00:47:25,980 --> 00:47:30,869
different species so this is iron and

1061
00:47:28,798 --> 00:47:34,500
silicon and zinc and chromium and

1062
00:47:30,869 --> 00:47:39,440
phosphorus this is in the SMC and we

1063
00:47:34,500 --> 00:47:42,389
plot basically how much stuff is missing

1064
00:47:39,440 --> 00:47:46,200
compared to sort of a rolled-up number

1065
00:47:42,389 --> 00:47:48,298
on that roll it up depletion so this is

1066
00:47:46,199 --> 00:47:51,480
more depletion that is you have more of

1067
00:47:48,298 --> 00:47:54,509
the metals in dust and then less

1068
00:47:51,480 --> 00:47:57,619
depletion less metals and dust and black

1069
00:47:54,510 --> 00:48:00,930

this black line here is what happens in

1070
00:47:57,619 --> 00:48:03,088
the milky way so this is comparing the

1071
00:48:00,929 --> 00:48:07,769
small Magellanic Cloud to the Milky Way

1072
00:48:03,088 --> 00:48:10,288
and by summing up all this all these

1073
00:48:07,769 --> 00:48:14,579
metals that are missing you can estimate

1074
00:48:10,289 --> 00:48:16,440
gas to dust ratios from basically what's

1075
00:48:14,579 --> 00:48:18,839
missing in a in a much more precise way

1076
00:48:16,440 --> 00:48:23,220
than we can with with the maps and so

1077
00:48:18,838 --> 00:48:26,250
it's a good check and so what we have

1078
00:48:23,219 --> 00:48:29,429
here is the hydrogen to dust mass ratio

1079
00:48:26,250 --> 00:48:33,088
the gas the dust ratio for the SMC the

1080
00:48:29,429 --> 00:48:35,909
LMC in the milky way and we can see that

1081
00:48:33,088 --> 00:48:37,949
it changes you have lines the sites that

1082
00:48:35,909 --> 00:48:40,500
they're things are more depleted that is

1083
00:48:37,949 --> 00:48:42,389
there's much more dust and you have

1084
00:48:40,500 --> 00:48:44,969
regions that are less depleted and so

1085
00:48:42,389 --> 00:48:47,429
this is other confirmation that there

1086
00:48:44,969 --> 00:48:49,679
are actually real variations of how much

1087
00:48:47,429 --> 00:48:51,239
dust is contained in different parts of

1088
00:48:49,679 --> 00:48:53,129
the galaxy there's real processing out

1089
00:48:51,239 --> 00:48:55,500
there it's both destroyed by the

1090
00:48:53,130 --> 00:48:57,028
supernova remnants as I showed but then

1091
00:48:55,500 --> 00:48:59,869
also in the colder clouds it really

1092
00:48:57,028 --> 00:49:02,130
seems that they it is growing again now

1093
00:48:59,869 --> 00:49:05,460
this is shorter of evidence that that

1094
00:49:02,130 --> 00:49:08,309
exists in existence proof but we are not

1095
00:49:05,460 --> 00:49:10,199
as far along in terms of coming up with

1096
00:49:08,309 --> 00:49:12,869
a rate like I showed you nice dust

1097
00:49:10,199 --> 00:49:15,179
production rates by the Evolve stars but

1098
00:49:12,869 --> 00:49:17,250
all we've done so far but I think it's a

1099
00:49:15,179 --> 00:49:19,739
big step forward is to show that yeah

1100
00:49:17,250 --> 00:49:21,269
actually this this stuff happens we

1101
00:49:19,739 --> 00:49:22,798
don't know how fast it happens how

1102
00:49:21,269 --> 00:49:25,829
effective it is but it's certainly

1103
00:49:22,798 --> 00:49:27,690
happening all right so let me go on to

1104
00:49:25,829 --> 00:49:29,940
the last loop here the young stars

1105
00:49:27,690 --> 00:49:32,400
forming the stars now in terms of the

1106
00:49:29,940 --> 00:49:33,920
life cycle of dust how this is important

1107
00:49:32,400 --> 00:49:35,519
is that the dust grains actually

1108
00:49:33,920 --> 00:49:36,840
disappear because

1109
00:49:35,519 --> 00:49:39,449
when you form a star it kind of takes

1110
00:49:36,840 --> 00:49:41,760
all the gas all the dust and it makes

1111
00:49:39,449 --> 00:49:45,960
them all atoms exactly highly ionized

1112

00:49:41,760 --> 00:49:48,690
atoms when it forms the star this is a

1113
00:49:45,960 --> 00:49:51,000
again a beautiful Hubble image of a

1114
00:49:48,690 --> 00:49:53,010
beautiful forming or young stellar

1115
00:49:51,000 --> 00:49:54,860
object because that's what we found in

1116
00:49:53,010 --> 00:49:57,660
the Magellanic Clouds you accelerate

1117
00:49:54,860 --> 00:50:03,180
s106 showing these beautiful bipolar

1118
00:49:57,659 --> 00:50:04,889
nebulas and why it's those or yang

1119
00:50:03,179 --> 00:50:08,909
stellar objects have different kinds of

1120
00:50:04,889 --> 00:50:11,480
evolutionary stages that we learn about

1121
00:50:08,909 --> 00:50:15,089
and can pick up with these observatories

1122
00:50:11,480 --> 00:50:19,619
here's a young protostar mean accreting

1123
00:50:15,090 --> 00:50:21,990
phase stage zero it's basically just a

1124
00:50:19,619 --> 00:50:24,059
bunch of cloud condensing onto thing

1125
00:50:21,989 --> 00:50:28,019
it's very cold it's really only seeing

1126
00:50:24,059 --> 00:50:29,519

with Herschel so we were good at finding

1127
00:50:28,019 --> 00:50:31,829
these types of objects and then we have

1128
00:50:29,519 --> 00:50:34,559
stage one object this is sort of an

1129
00:50:31,829 --> 00:50:37,319
accreting protostar where you have a

1130
00:50:34,559 --> 00:50:40,320
disc it's getting it's turned on

1131
00:50:37,320 --> 00:50:43,230
you have been frit excesses and then

1132
00:50:40,320 --> 00:50:45,150
stage two is when basically that

1133
00:50:43,230 --> 00:50:47,280
envelope is gone but you still have this

1134
00:50:45,150 --> 00:50:49,710
disk and planets will start forming in

1135
00:50:47,280 --> 00:50:53,910
stage three which I won't be talking

1136
00:50:49,710 --> 00:50:55,440
about at all really two or three stage

1137
00:50:53,909 --> 00:51:00,480
three is where basically you have

1138
00:50:55,440 --> 00:51:02,750
planets and and there you're seeing a

1139
00:51:00,480 --> 00:51:06,329
book sort of Kuiper belt type objects

1140
00:51:02,750 --> 00:51:08,039
all right so small Magellanic Cloud

1141
00:51:06,329 --> 00:51:09,690
why so Canada so again how do we find

1142
00:51:08,039 --> 00:51:12,210
these so I talk to you a little bit

1143
00:51:09,690 --> 00:51:14,490
these this is maybe somewhat familiar

1144
00:51:12,210 --> 00:51:17,880
we use these color-magnitude diagram yet

1145
00:51:14,489 --> 00:51:21,989
again this is eight versus eight minus

1146
00:51:17,880 --> 00:51:25,619
24 and the thing with the why shows is

1147
00:51:21,989 --> 00:51:28,019
that before the launch of spitzer there

1148
00:51:25,619 --> 00:51:29,969
was only one known in a small magellanic

1149
00:51:28,019 --> 00:51:32,489
cloud and in the large magellanic cloud

1150
00:51:29,969 --> 00:51:34,139
there were only 20 so to really

1151
00:51:32,489 --> 00:51:36,359
understand this we actually had to find

1152
00:51:34,139 --> 00:51:38,099
all the all the young stellar objects

1153
00:51:36,360 --> 00:51:39,870
know this was a big discovery just

1154
00:51:38,099 --> 00:51:42,329
trying to find them and identify them

1155
00:51:39,869 --> 00:51:44,569
for the first time so it was pretty

1156
00:51:42,329 --> 00:51:47,849
exciting this is a lot of cool stuff

1157
00:51:44,570 --> 00:51:49,509
what I want to show over here is these

1158
00:51:47,849 --> 00:51:50,889
are all the evolved stars

1159
00:51:49,509 --> 00:51:52,748
use all the ones I talked about at the

1160
00:51:50,889 --> 00:51:54,849
beginning of the talk the ones that are

1161
00:51:52,748 --> 00:51:56,798
dying there's confusion with the ones

1162
00:51:54,849 --> 00:51:59,889
that are being born because they both

1163
00:51:56,798 --> 00:52:02,588
power stars with dust around it and

1164
00:51:59,889 --> 00:52:04,539
here's the young ones these are the ones

1165
00:52:02,588 --> 00:52:06,759
where we were after and there were some

1166
00:52:04,539 --> 00:52:09,429
studies done before tonight to show some

1167
00:52:06,759 --> 00:52:12,248
of them and then this is what we this is

1168
00:52:09,429 --> 00:52:14,019
this was our guidance so in grey here

1169

00:52:12,248 --> 00:52:15,818
and all the things are it's basically

1170
00:52:14,018 --> 00:52:17,078
the whole catalog for the element for

1171
00:52:15,818 --> 00:52:20,498
the small Magellanic Cloud the whole

1172
00:52:17,079 --> 00:52:24,399
catalog of all the sources and in amber

1173
00:52:20,498 --> 00:52:26,379
here is the model predictions of where

1174
00:52:24,398 --> 00:52:29,318
do you expect to find them in the

1175
00:52:26,380 --> 00:52:31,479
color-magnitude space and then here well

1176
00:52:29,318 --> 00:52:32,558
this is a problem the problem here is

1177
00:52:31,478 --> 00:52:36,038
that there are a lot of background

1178
00:52:32,559 --> 00:52:38,079
galaxies to the LMC that confuse us with

1179
00:52:36,039 --> 00:52:41,079
whether it's a star or a galaxy

1180
00:52:38,079 --> 00:52:43,329
so the initial survey is the one

1181
00:52:41,079 --> 00:52:47,259
published by this former postdoc of mine

1182
00:52:43,329 --> 00:52:49,179
marta Savio basically went for the easy

1183
00:52:47,259 --> 00:52:50,708

stuff the really dusty stuff and the

1184
00:52:49,179 --> 00:52:54,548
bright stuffs are kind of the more

1185
00:52:50,708 --> 00:52:58,028
massive young stellar objects and so

1186
00:52:54,548 --> 00:53:01,509
what we did is we found actually 1100

1187
00:52:58,028 --> 00:53:03,398
yso candidates in the SMC that's a

1188
00:53:01,509 --> 00:53:06,039
thousand times more than we we knew

1189
00:53:03,398 --> 00:53:09,518
before before the survey was done a

1190
00:53:06,039 --> 00:53:13,719
thousand times more objects and this is

1191
00:53:09,518 --> 00:53:15,638
the location of all of them so what are

1192
00:53:13,719 --> 00:53:17,798
some of the things that are interesting

1193
00:53:15,639 --> 00:53:19,479
particularly with respect to this dust

1194
00:53:17,798 --> 00:53:22,809
lifecycle is well you can start making

1195
00:53:19,478 --> 00:53:25,178
plots histogram of the stellar mass here

1196
00:53:22,809 --> 00:53:28,119
you can see we're kind of biased to the

1197
00:53:25,179 --> 00:53:31,119
more massive ones here's the luminosity

1198
00:53:28,119 --> 00:53:32,919
plot again the more luminous ones but

1199
00:53:31,119 --> 00:53:35,229
there been lots of theoretical studies

1200
00:53:32,918 --> 00:53:36,788
shown of figuring out what an initial

1201
00:53:35,228 --> 00:53:38,438
mass function is and this is a

1202
00:53:36,789 --> 00:53:40,269
characteristic initial mass function

1203
00:53:38,438 --> 00:53:42,578
that we just fit over the part that

1204
00:53:40,268 --> 00:53:45,188
we're most confident with when we figure

1205
00:53:42,579 --> 00:53:47,289
out how much how many stars are being

1206
00:53:45,188 --> 00:53:50,678
born now and from that we can come up

1207
00:53:47,289 --> 00:53:53,109
with a star formation rate or asfr and

1208
00:53:50,679 --> 00:53:56,469
that star formation rate in the SMC is

1209
00:53:53,108 --> 00:53:58,088
0.06 solar masses per year and so that's

1210
00:53:56,469 --> 00:53:59,559
the real which stars are forming if you

1211
00:53:58,088 --> 00:54:01,088
have a guess the dust' ratio you can

1212
00:53:59,559 --> 00:54:02,160
also say well how much dust is

1213
00:54:01,088 --> 00:54:08,929
disappearing

1214
00:54:02,159 --> 00:54:11,098
forming these stars alright going to the

1215
00:54:08,929 --> 00:54:15,000
less-evolved the young stellar object

1216
00:54:11,099 --> 00:54:17,519
and dust calms we got those from the

1217
00:54:15,000 --> 00:54:21,059
Herschel Heritage Survey so this is H

1218
00:54:17,518 --> 00:54:23,848
alpha spire 250 microns and this is our

1219
00:54:21,059 --> 00:54:26,548
band merge catalog and then bottom here

1220
00:54:23,849 --> 00:54:29,039
you can see where we think all the Y

1221
00:54:26,548 --> 00:54:32,608
shows are located and then we also found

1222
00:54:29,039 --> 00:54:34,980
kind of preforming stars sort of dense

1223
00:54:32,608 --> 00:54:36,659
clump things and then you can see we

1224
00:54:34,980 --> 00:54:38,190
have lots of contamination from the

1225
00:54:36,659 --> 00:54:39,989
background galaxies at these wavelengths

1226

00:54:38,190 --> 00:54:42,389
so this was a very tricky problem to

1227
00:54:39,989 --> 00:54:43,768
separate what's really distant in high

1228
00:54:42,389 --> 00:54:47,098
redshift and what is part of the

1229
00:54:43,768 --> 00:54:51,689
galaxies but we ended up with you can

1230
00:54:47,099 --> 00:54:55,920
see on the order of almost 800 young

1231
00:54:51,690 --> 00:54:58,019
stellar objects with Herschel alright so

1232
00:54:55,920 --> 00:54:58,980
so this is kind of a little bit at the

1233
00:54:58,018 --> 00:55:01,078
end of my story

1234
00:54:58,980 --> 00:55:04,199
so I've stepped you through that whole

1235
00:55:01,079 --> 00:55:04,619
life cycle now but then what is the

1236
00:55:04,199 --> 00:55:06,268
ledger

1237
00:55:04,619 --> 00:55:08,400
what's the ledger book so at the

1238
00:55:06,268 --> 00:55:10,229
beginning I said okay what is how much

1239
00:55:08,400 --> 00:55:13,470
dust is in the is m and so in this

1240
00:55:10,230 --> 00:55:15,690

column here it's always the LMC this is

1241
00:55:13,469 --> 00:55:19,679
always the SMC I'm going to focus on the

1242
00:55:15,690 --> 00:55:21,990
LMC numbers and quote those and remember

1243
00:55:19,679 --> 00:55:25,318
the SMC you'll see is about factor of 10

1244
00:55:21,989 --> 00:55:27,508
lower so the dust mass seven point three

1245
00:55:25,318 --> 00:55:30,659
times ten to the five solar masses of

1246
00:55:27,509 --> 00:55:32,909
dust how much dust is being returned

1247
00:55:30,659 --> 00:55:35,338
from these stellar winds from egb stars

1248
00:55:32,909 --> 00:55:37,920
where it supergiant's LBB masses if you

1249
00:55:35,338 --> 00:55:42,750
sum all that up you have 2.5 times 10 of

1250
00:55:37,920 --> 00:55:45,690
-5 solar masses per year and then here

1251
00:55:42,750 --> 00:55:48,509
you have supernova dust production this

1252
00:55:45,690 --> 00:55:51,838
was based on the 87 a result 2 times 10

1253
00:55:48,509 --> 00:55:54,750
to minus three solar masses per year and

1254
00:55:51,838 --> 00:55:59,219
then you have dust destruction by

1255
00:55:54,750 --> 00:56:00,630
supernovae 2 times 10 to minus 2 solar

1256
00:55:59,219 --> 00:56:03,778
masses per year so you can see the

1257
00:56:00,630 --> 00:56:08,278
destruction seems to be bigger star

1258
00:56:03,778 --> 00:56:09,268
formation rate 0.1 times 10.1 solar

1259
00:56:08,278 --> 00:56:10,949
masses per year

1260
00:56:09,268 --> 00:56:13,048
stellar astray ssin of death so that's

1261
00:56:10,949 --> 00:56:15,629
sort of multiplying this time to dust

1262
00:56:13,048 --> 00:56:17,159
the gas ratio so this is how much dust

1263
00:56:15,630 --> 00:56:19,619
appears because we're just warming stars

1264
00:56:17,159 --> 00:56:22,769
two times some of mines for solar masses

1265
00:56:19,619 --> 00:56:27,449
per year so what we have here is a net

1266
00:56:22,769 --> 00:56:29,610
loss of dust at 1.8 times 10 to minus 2

1267
00:56:27,449 --> 00:56:32,429
solar masses per year it's that's kind

1268
00:56:29,610 --> 00:56:34,980
of a high rate of deaths now you'll note

1269
00:56:32,429 --> 00:56:38,669
that I don't have a calculation for the

1270
00:56:34,980 --> 00:56:40,889
dust grouse in the is M because we don't

1271
00:56:38,670 --> 00:56:42,420
have ways to measure that yet we know

1272
00:56:40,889 --> 00:56:45,900
something's happening but we don't know

1273
00:56:42,420 --> 00:56:50,940
what the rate but because this number is

1274
00:56:45,900 --> 00:56:55,730
negative I still ask this question of

1275
00:56:50,940 --> 00:56:58,289
why does this galaxy have dust and

1276
00:56:55,730 --> 00:57:00,269
before I take your questions I just want

1277
00:56:58,289 --> 00:57:02,279
to point out that doing this type of

1278
00:57:00,269 --> 00:57:04,590
work I mean the amount of discoveries we

1279
00:57:02,280 --> 00:57:06,450
made in these programs is tremendous and

1280
00:57:04,590 --> 00:57:08,910
it's been really rewarding but it is not

1281
00:57:06,449 --> 00:57:11,839
possible without a large team of people

1282
00:57:08,909 --> 00:57:18,089
because all these calculations and work

1283

00:57:11,840 --> 00:57:21,980
requires many hands so anyway I thank

1284
00:57:18,090 --> 00:57:21,980
them and I think you for listening to me

1285
00:57:34,909 --> 00:57:38,239
Yeah right

1286
00:57:52,588 --> 00:57:58,650
in terms of interaction physical

1287
00:57:54,778 --> 00:58:01,498
dynamical interaction not not as

1288
00:57:58,650 --> 00:58:04,950
intensely as the LMC the SMC do with

1289
00:58:01,498 --> 00:58:08,219
each other and this type of study of

1290
00:58:04,949 --> 00:58:09,960
dust evolution has not been done in the

1291
00:58:08,219 --> 00:58:12,719
mini Andromeda galaxy although I'm

1292
00:58:09,960 --> 00:58:15,179
thinking about it with James Webb when

1293
00:58:12,719 --> 00:58:16,828
James why but the the two satellite

1294
00:58:15,179 --> 00:58:18,659
galaxies of Andromeda are mostly

1295
00:58:16,829 --> 00:58:23,099
ellipticals do they have significant

1296
00:58:18,659 --> 00:58:25,798
dust and ice the close-in ones are too

1297
00:58:23,099 --> 00:58:28,079

elliptical with dwarf ellipticals yeah I

1298
00:58:25,798 --> 00:58:29,190
don't know my postdoc Libby's actually

1299
00:58:28,079 --> 00:58:31,559
going to try to measure the dust

1300
00:58:29,190 --> 00:58:32,789
production for him 32 okay

1301
00:58:31,559 --> 00:58:34,798
I'm just to see what's being produced

1302
00:58:32,789 --> 00:58:36,589
but there is not a lot of gas and dust

1303
00:58:34,798 --> 00:58:39,239
there's not a lot of interstellar medium

1304
00:58:36,588 --> 00:58:42,469
so it's hard to measure what's what's in

1305
00:58:39,239 --> 00:58:42,470
the interstellar medium in the clouds

1306
00:58:46,090 --> 00:58:57,010
oh right okay we need to repeat the

1307
00:58:55,659 --> 00:58:59,469
question for though oh right for the eye

1308
00:58:57,010 --> 00:59:02,830
okay so the question was you mentioned

1309
00:58:59,469 --> 00:59:06,129
that supernovae destroyed us but in 1987

1310
00:59:02,829 --> 00:59:09,849
au seed us so why do you see it in that

1311
00:59:06,130 --> 00:59:11,670
case and so the difference or maybe I

1312
00:59:09,849 --> 00:59:15,130
didn't make very clear is that the

1313
00:59:11,670 --> 00:59:18,639
supernova 1987a the ejecta from the star

1314
00:59:15,130 --> 00:59:22,090
I mean the explosion has created dust

1315
00:59:18,639 --> 00:59:24,429
that much dust and it is but it's the

1316
00:59:22,090 --> 00:59:26,230
shockwave of the supernova remnant going

1317
00:59:24,429 --> 00:59:28,809
out that is destroying the dust outside

1318
00:59:26,230 --> 00:59:32,530
of that so it's destroying the dust in

1319
00:59:28,809 --> 00:59:36,190
the interstellar medium so that's that's

1320
00:59:32,530 --> 00:59:38,350
why we saw it also it's very young super

1321
00:59:36,190 --> 00:59:39,700
number 87 a is really experienced what

1322
00:59:38,349 --> 00:59:41,079
they call a reverse shock where the

1323
00:59:39,699 --> 00:59:43,329
shocks that would come back and so a lot

1324
00:59:41,079 --> 00:59:44,679
of people say okay well to have solar

1325
00:59:43,329 --> 00:59:45,909
massive dust but all of its gonna go

1326
00:59:44,679 --> 00:59:47,649
away with the reverse shock well that's

1327
00:59:45,909 --> 00:59:50,469
something we'll be able to explore

1328
00:59:47,650 --> 00:59:52,660
actually over the next decade how much

1329
00:59:50,469 --> 00:59:54,279
how much does get destroyed so you're

1330
00:59:52,659 --> 00:59:56,679
expecting the reverse shot to hit in the

1331
00:59:54,280 --> 01:00:00,340
next decade that's what someone was

1332
00:59:56,679 --> 01:00:02,829
telling me yeah I just find 87 is so fun

1333
01:00:00,340 --> 01:00:04,660
it is we have to watch things happen in

1334
01:00:02,829 --> 01:00:06,699
real time that you've never been able to

1335
01:00:04,659 --> 01:00:08,440
see so with James Webb I'm gonna use

1336
01:00:06,699 --> 01:00:10,239
some of my guaranteed time to actually

1337
01:00:08,440 --> 01:00:11,769
try to get a spectrum of that dust to

1338
01:00:10,239 --> 01:00:22,419
figure out what is it made of because

1339
01:00:11,769 --> 01:00:25,030
it's limiting our models yes it means

1340

01:00:22,420 --> 01:00:27,789
that well dust is it's sort of all these

1341
01:00:25,030 --> 01:00:29,560
metals that are solid in a solid form so

1342
01:00:27,789 --> 01:00:33,340
when you mean destroyed it means it's

1343
01:00:29,559 --> 01:00:35,259
shattered all into the atoms so that's

1344
01:00:33,340 --> 01:00:37,030
why these depletion measurements we're

1345
01:00:35,260 --> 01:00:39,850
just looking at how many how many how

1346
01:00:37,030 --> 01:00:41,610
much atoms of iron is there in the gas

1347
01:00:39,849 --> 01:00:44,710
and how much should there be in that's

1348
01:00:41,610 --> 01:00:48,220
the fact that whatever's missing sort of

1349
01:00:44,710 --> 01:00:50,650
the missing so we had a question from

1350
01:00:48,219 --> 01:00:52,899
online yes they wanted to know our dust

1351
01:00:50,650 --> 01:00:55,420
grains positively or negatively charged

1352
01:00:52,900 --> 01:00:58,119
are they mostly neutral oh that's a very

1353
01:00:55,420 --> 01:01:02,588
good question very sophisticated

1354
01:00:58,119 --> 01:01:04,809

they are neutral inside the dense clouds

1355
01:01:02,588 --> 01:01:06,818
but near the surfaces where their shine

1356
01:01:04,809 --> 01:01:20,769
by light they tend to be positively

1357
01:01:06,818 --> 01:01:23,858
charged questions from the room right so

1358
01:01:20,768 --> 01:01:26,618
hydrogen's the bulk of it but then it's

1359
01:01:23,858 --> 01:01:28,509
like healing there's some fraction of it

1360
01:01:26,619 --> 01:01:33,068
that's helium that we that we correct

1361
01:01:28,509 --> 01:01:35,349
for no I mean hydrogen I mean basically

1362
01:01:33,068 --> 01:01:37,630
if you can account for all the hydrogen

1363
01:01:35,349 --> 01:01:39,579
atoms and then correct for the helium

1364
01:01:37,630 --> 01:01:42,249
you you pretty much know how much gas is

1365
01:01:39,579 --> 01:01:45,130
there I mean we use all sorts of gas

1366
01:01:42,248 --> 01:01:47,739
tracers to help us like for the cold

1367
01:01:45,130 --> 01:01:52,630
molecular gas for h2 we can't really

1368
01:01:47,739 --> 01:01:54,098
trace that very well with well with the

1369
01:01:52,630 --> 01:01:56,108
transitions because it's a diatomic

1370
01:01:54,099 --> 01:01:59,109
molecule so we tend to use carbon

1371
01:01:56,108 --> 01:02:01,778
monoxide or Co because it's asymmetric

1372
01:01:59,108 --> 01:02:04,630
we can trace its rotational lines at a

1373
01:02:01,778 --> 01:02:09,268
low temperature and be able to use it as

1374
01:02:04,630 --> 01:02:11,588
a tracer for the molecular hydrogen is

1375
01:02:09,268 --> 01:02:15,578
that's part of the uncertainty and that

1376
01:02:11,588 --> 01:02:19,239
gas to dust ratio map that I showed you

1377
01:02:15,579 --> 01:02:22,119
is it's very difficult to to map where

1378
01:02:19,239 --> 01:02:24,099
the hydrogen is okay so we have another

1379
01:02:22,119 --> 01:02:25,778
question from online wanting to know

1380
01:02:24,099 --> 01:02:27,640
about the dust clouds themselves what

1381
01:02:25,778 --> 01:02:29,349
are the it's like the average density in

1382
01:02:27,639 --> 01:02:30,788
these dust clouds I guess they'd

1383
01:02:29,349 --> 01:02:33,789
probably want to know the temperature -

1384
01:02:30,789 --> 01:02:38,319
okay the temperature in the clouds in

1385
01:02:33,789 --> 01:02:42,130
the largeman jóhanna around 25 Kelvin 22

1386
01:02:38,318 --> 01:02:44,498
Kelvin so I mean really cold but it's

1387
01:02:42,130 --> 01:02:46,568
colder than 3 Kelvin which is the Cosmic

1388
01:02:44,498 --> 01:02:50,318
Microwave Background but that's still

1389
01:02:46,568 --> 01:02:52,719
minus 250 or so yeah you wouldn't

1390
01:02:50,318 --> 01:02:59,980
centigrade there which is around minus

1391
01:02:52,719 --> 01:03:03,518
500 yeah it's not it's not like being at

1392
01:02:59,980 --> 01:03:05,349
the beach or something I mean actually

1393
01:03:03,518 --> 01:03:07,929
sand grains is kind of an analogy to all

1394
01:03:05,349 --> 01:03:09,980
the silicate grains and stuff but the

1395
01:03:07,929 --> 01:03:15,169
densities it's very low

1396
01:03:09,980 --> 01:03:16,940
gosh I mean some of the desk clouds you

1397

01:03:15,170 --> 01:03:20,329
know and I'm going to trace this in

1398
01:03:16,940 --> 01:03:22,929
terms of the hydrogen content right it

1399
01:03:20,329 --> 01:03:26,119
could be like there might be a hundred

1400
01:03:22,929 --> 01:03:28,069
per cubic centimeter right that's I mean

1401
01:03:26,119 --> 01:03:29,990
it's really I mean it's rarified it's

1402
01:03:28,070 --> 01:03:32,240
more rarefied than any vacuum that we

1403
01:03:29,989 --> 01:03:34,189
can create on earth it's just very it's

1404
01:03:32,239 --> 01:03:36,259
very rarefied and the reason we can see

1405
01:03:34,190 --> 01:03:39,920
is that we see large columns of it and

1406
01:03:36,260 --> 01:03:42,230
you map it because there's just lots it

1407
01:03:39,920 --> 01:03:44,838
the clouds big it's massive but it's

1408
01:03:42,230 --> 01:03:47,210
very diffused right so it's like colder

1409
01:03:44,838 --> 01:03:48,889
than anything on earth and more rarefied

1410
01:03:47,210 --> 01:04:02,119
than anything on earth but let me call

1411
01:03:48,889 --> 01:04:03,049

it this these giant dust clouds yes it

1412
01:04:02,119 --> 01:04:05,599
does

1413
01:04:03,050 --> 01:04:07,010
I mean our earth is made of dust grains

1414
01:04:05,599 --> 01:04:10,309
these dust grains they've been floating

1415
01:04:07,010 --> 01:04:13,820
around but that's it creates things only

1416
01:04:10,309 --> 01:04:15,650
when it gets gathered up right it

1417
01:04:13,820 --> 01:04:17,568
creates a lot of hassle for all my

1418
01:04:15,650 --> 01:04:19,430
optical Astronomy buddies in the house

1419
01:04:17,568 --> 01:04:21,199
in this building because they're like ah

1420
01:04:19,429 --> 01:04:23,419
that's I've gotta correct for it cuz

1421
01:04:21,199 --> 01:04:26,179
it's reddening my observations and it's

1422
01:04:23,420 --> 01:04:29,599
making it dimmer so it causes a nuisance

1423
01:04:26,179 --> 01:04:33,379
that way but in terms of creating things

1424
01:04:29,599 --> 01:04:35,150
when a stars formed I showed you that

1425
01:04:33,380 --> 01:04:37,068
disk and planets form around it and the

1426
01:04:35,150 --> 01:04:39,889
planets are really formed from the dust

1427
01:04:37,068 --> 01:04:43,130
the dust condenses nicely at the center

1428
01:04:39,889 --> 01:04:44,449
settles better than the gas and it and

1429
01:04:43,130 --> 01:04:45,740
that's actually a different mystery as

1430
01:04:44,449 --> 01:04:47,629
someone else can talk to you about but

1431
01:04:45,739 --> 01:04:49,578
how do you get these grains to build up

1432
01:04:47,630 --> 01:04:51,710
to fill to create plant if they actually

1433
01:04:49,579 --> 01:04:54,079
haven't figured that out yet because

1434
01:04:51,710 --> 01:04:56,210
it's hard to go from okay you can

1435
01:04:54,079 --> 01:04:57,650
coagulate in there bigger bigger but at

1436
01:04:56,210 --> 01:04:59,869
that certain point they can't figure out

1437
01:04:57,650 --> 01:05:02,539
how they stick well enough together to

1438
01:04:59,869 --> 01:05:06,220
build something bigger that's a that's a

1439
01:05:02,539 --> 01:05:06,219
difficulty for them Peter

1440
01:05:12,690 --> 01:05:22,960
no no you mean to imply you mean to a

1441
01:05:20,230 --> 01:05:25,750
planet is ever to me no I wouldn't call

1442
01:05:22,960 --> 01:05:27,760
that destruction to me right I would say

1443
01:05:25,750 --> 01:05:31,840
that's creating into a really large dust

1444
01:05:27,760 --> 01:05:36,550
grain you live on a giant doesn't

1445
01:05:31,840 --> 01:05:49,920
everybody know because it's still a

1446
01:05:36,550 --> 01:05:49,920
solid phase yeah

1447
01:05:53,769 --> 01:05:58,800
they won't write

1448
01:05:59,280 --> 01:06:04,510
okay so I'll have two answers one is

1449
01:06:02,050 --> 01:06:06,700
that I mean we we certainly observe dust

1450
01:06:04,510 --> 01:06:09,160
and gas clouds in our solar neighborhood

1451
01:06:06,699 --> 01:06:10,899
that you know people have observed in

1452
01:06:09,159 --> 01:06:13,058
fact this whole depletion stuff I talked

1453
01:06:10,900 --> 01:06:15,160
about all of that has been done very

1454

01:06:13,059 --> 01:06:19,300
local to this to the Sun because it's

1455
01:06:15,159 --> 01:06:21,848
difficult to go beyond that I think in

1456
01:06:19,300 --> 01:06:24,670
terms of our solar system sweeping

1457
01:06:21,849 --> 01:06:26,109
through next hundred years well I don't

1458
01:06:24,670 --> 01:06:30,220
know I mean we might be passing through

1459
01:06:26,108 --> 01:06:33,630
something now I did hear a paper where

1460
01:06:30,219 --> 01:06:37,118
someone used the Voyager spacecraft data

1461
01:06:33,630 --> 01:06:38,829
to understand interstellar grain dust

1462
01:06:37,119 --> 01:06:42,068
grains that were coming into the solar

1463
01:06:38,829 --> 01:06:45,670
system so it's it's quite possible that

1464
01:06:42,068 --> 01:06:48,039
you know we are getting I mean that we

1465
01:06:45,670 --> 01:06:50,889
are getting bombarded but it's and it's

1466
01:06:48,039 --> 01:06:53,108
difficult that it was a fascinating

1467
01:06:50,889 --> 01:06:57,129
paper because somehow they were able to

1468
01:06:53,108 --> 01:06:59,529

know it was clouds coming out the Oort

1469
01:06:57,130 --> 01:07:01,869
cloud Oh with the with the Kuiper belt

1470
01:06:59,530 --> 01:07:03,700
objects and stuff like that I mean that

1471
01:07:01,869 --> 01:07:06,160
but that's part of the solar system I

1472
01:07:03,699 --> 01:07:08,858
mean so that I think he was asking like

1473
01:07:06,159 --> 01:07:15,690
a different interstellar cloud that a

1474
01:07:08,858 --> 01:07:15,690
diffuse cloud great

1475
01:07:23,068 --> 01:07:29,858
it would be I mean and actually

1476
01:07:26,099 --> 01:07:32,220
something there's a group in University

1477
01:07:29,858 --> 01:07:33,940
of Washington in st. Louis that is

1478
01:07:32,219 --> 01:07:35,769
internationally famous they have a

1479
01:07:33,940 --> 01:07:38,108
meteoroid lab in which they take

1480
01:07:35,769 --> 01:07:39,818
meteorites and they smash them out to

1481
01:07:38,108 --> 01:07:41,429
little parts and they try to identify

1482
01:07:39,818 --> 01:07:45,159
which dust grains are what they call

1483
01:07:41,429 --> 01:07:49,538
pre-solar grains and so they've actually

1484
01:07:45,159 --> 01:07:53,558
have found and analyzed dust grains that

1485
01:07:49,539 --> 01:07:55,630
were formed in an Ag B star wind and

1486
01:07:53,559 --> 01:07:58,089
they're able to identify it because the

1487
01:07:55,630 --> 01:08:01,150
isotopic ratio of like a carbon star has

1488
01:07:58,088 --> 01:08:04,150
a very unique signature when you dredge

1489
01:08:01,150 --> 01:08:07,180
up the carbon the carbon 12 to carbon 13

1490
01:08:04,150 --> 01:08:09,010
ratio is very different than you know

1491
01:08:07,179 --> 01:08:11,288
what we find normally in the in the

1492
01:08:09,010 --> 01:08:12,670
universe and so they're able to identify

1493
01:08:11,289 --> 01:08:15,250
that and actually study those grains

1494
01:08:12,670 --> 01:08:17,560
incident that's probably the closest

1495
01:08:15,250 --> 01:08:20,170
that I know where you come to try to

1496
01:08:17,560 --> 01:08:22,539
study something that was created outside

1497
01:08:20,170 --> 01:08:24,850
and actually somehow survived all the

1498
01:08:22,539 --> 01:08:28,509
processing I've talked about I mean I

1499
01:08:24,850 --> 01:08:29,739
think people were floored when they

1500
01:08:28,509 --> 01:08:32,588
heard what do you mean you found

1501
01:08:29,738 --> 01:08:34,389
something that that pre-existed the

1502
01:08:32,588 --> 01:08:37,390
solar system and wasn't smashed to

1503
01:08:34,390 --> 01:08:40,329
smithereens and rebuilt yeah and let me

1504
01:08:37,390 --> 01:08:42,880
just set timescale the Sun moves around

1505
01:08:40,329 --> 01:08:46,028
the center of our galaxy in about 200 to

1506
01:08:42,880 --> 01:08:47,469
220 million years so a hundred years is

1507
01:08:46,029 --> 01:08:47,949
nothing to the sun's motion through the

1508
01:08:47,469 --> 01:08:50,649
galaxy

1509
01:08:47,948 --> 01:08:52,658
so so we well I'm sure that in our

1510
01:08:50,649 --> 01:08:53,889
travels we've made about eighteen orbits

1511

01:08:52,658 --> 01:08:56,619
around the center of the galaxy we have

1512
01:08:53,890 --> 01:08:58,329
passed through dust clouds right but

1513
01:08:56,619 --> 01:09:00,009
it's not something that a hundred years

1514
01:08:58,329 --> 01:09:03,640
is going to make a lot of difference to

1515
01:09:00,009 --> 01:09:06,119
our position in the galaxy okay other

1516
01:09:03,640 --> 01:09:06,119
questions

1517
01:09:31,880 --> 01:09:35,329
okay you have to summarize that for the

1518
01:09:33,560 --> 01:09:37,460
online cousin up to here at the front

1519
01:09:35,329 --> 01:09:39,680
right so what I hear and please correct

1520
01:09:37,460 --> 01:09:42,409
me if I'm ever mind you're asking that

1521
01:09:39,680 --> 01:09:43,789
you imagine different stars different

1522
01:09:42,409 --> 01:09:48,399
masses will have different explosive

1523
01:09:43,789 --> 01:09:51,979
forces and that's completely true and

1524
01:09:48,399 --> 01:09:53,629
how does that how does it affect is it

1525
01:09:51,979 --> 01:09:55,729

because there's this difference in the

1526
01:09:53,630 --> 01:10:07,489
carbon and silicon destruction does that

1527
01:09:55,729 --> 01:10:10,129
affect right so the question was do we

1528
01:10:07,489 --> 01:10:12,109
have evidence of how the dust get right

1529
01:10:10,130 --> 01:10:14,359
is there a correlation between this

1530
01:10:12,109 --> 01:10:17,659
supernova explosion and the type of

1531
01:10:14,359 --> 01:10:19,729
destruction that it does all I can tell

1532
01:10:17,659 --> 01:10:21,949
you is that not as much evidence as we

1533
01:10:19,729 --> 01:10:23,569
would like I mean there are a couple of

1534
01:10:21,949 --> 01:10:26,149
supernova remnants that have been

1535
01:10:23,569 --> 01:10:30,439
studied in some detail to show that dust

1536
01:10:26,149 --> 01:10:33,649
is destroyed but a lot of what a lot of

1537
01:10:30,439 --> 01:10:36,079
what is modeled is very theoretical and

1538
01:10:33,649 --> 01:10:38,089
that's why there's this whole huge

1539
01:10:36,079 --> 01:10:40,430
uncertainty like I've told you this

1540
01:10:38,090 --> 01:10:44,079
death destruction so some people in the

1541
01:10:40,430 --> 01:10:47,420
in in the field say well okay but that's

1542
01:10:44,079 --> 01:10:49,159
that this is really a calculation this

1543
01:10:47,420 --> 01:10:52,359
is really a theoretical count it's not

1544
01:10:49,159 --> 01:10:55,130
as not as known as well as we might like

1545
01:10:52,359 --> 01:10:59,149
and so some people dispute that this

1546
01:10:55,130 --> 01:11:00,859
dust is destroyed this efficiently other

1547
01:10:59,149 --> 01:11:07,009
people believe this is gospel that's

1548
01:11:00,859 --> 01:11:08,449
mainly the theorists and the you know

1549
01:11:07,010 --> 01:11:10,789
then they say and the theorists say well

1550
01:11:08,449 --> 01:11:13,369
what this proves is that dust has to

1551
01:11:10,789 --> 01:11:15,560
grow in the is M at a rate to nullify

1552
01:11:13,369 --> 01:11:17,840
that so basically things are steady

1553
01:11:15,560 --> 01:11:21,650
state and hence we have dust in a galaxy

1554
01:11:17,840 --> 01:11:23,810
but I think I mean this I would like to

1555
01:11:21,649 --> 01:11:25,639
see more observational investigation

1556
01:11:23,810 --> 01:11:27,770
today I mean we could do what you just

1557
01:11:25,640 --> 01:11:30,680
said and can we find a correlation

1558
01:11:27,770 --> 01:11:33,470
between a massive explosion and how much

1559
01:11:30,680 --> 01:11:36,200
dust is destroyed and really find har

1560
01:11:33,470 --> 01:11:37,310
vêtements or that that would be that

1561
01:11:36,199 --> 01:11:39,800
would be really good that would be a

1562
01:11:37,310 --> 01:11:40,590
huge step forward in my opinion we could

1563
01:11:39,800 --> 01:11:42,270
do that

1564
01:11:40,590 --> 01:11:55,170
but we don't we don't quite have that

1565
01:11:42,270 --> 01:12:00,480
yet let's see well a couple things it's

1566
01:11:55,170 --> 01:12:03,480
a bit of a secure Espace for me I was it

1567
01:12:00,479 --> 01:12:05,189
was a bit random how I got here in the

1568

01:12:03,479 --> 01:12:08,309
sense that I was always interested in

1569
01:12:05,189 --> 01:12:11,399
astronomy as a as a child like in age 13

1570
01:12:08,310 --> 01:12:13,050
I took a science course and I have to

1571
01:12:11,399 --> 01:12:15,118
say middle school teachers if any of you

1572
01:12:13,050 --> 01:12:17,429
are out there you have probably the most

1573
01:12:15,118 --> 01:12:21,299
impact on the kids the career career

1574
01:12:17,429 --> 01:12:22,679
decision but I took a class and every

1575
01:12:21,300 --> 01:12:25,349
everything they talked to me about was

1576
01:12:22,679 --> 01:12:26,969
like meteorology a meteorologist or Ino

1577
01:12:25,349 --> 01:12:28,319
jealous oh I want to be a geologist and

1578
01:12:26,969 --> 01:12:30,359
we ended with astronomy and I was like

1579
01:12:28,319 --> 01:12:33,868
oh man I've got to be an astronomer and

1580
01:12:30,359 --> 01:12:35,819
and then I found I then I took physics

1581
01:12:33,868 --> 01:12:37,439
I think the following year and I thought

1582
01:12:35,819 --> 01:12:39,809

you know it's quite good I was good at

1583
01:12:37,439 --> 01:12:44,759
math and physics less good at English

1584
01:12:39,810 --> 01:12:46,289
and then when I went to school I kind of

1585
01:12:44,760 --> 01:12:49,770
I went to University of Maryland College

1586
01:12:46,289 --> 01:12:51,420
Park actually undergrad I said well you

1587
01:12:49,770 --> 01:12:53,010
can't get a job as an astronomer so I

1588
01:12:51,420 --> 01:12:54,420
went into logical engineering I have a

1589
01:12:53,010 --> 01:12:58,170
degree in electrical engineering and

1590
01:12:54,420 --> 01:13:00,118
mathematics but a neighbor of mine who

1591
01:12:58,170 --> 01:13:01,829
was an astronomer you know as a bright

1592
01:13:00,118 --> 01:13:03,469
student and said hey do you want to work

1593
01:13:01,829 --> 01:13:06,689
with me and over the summer I was like

1594
01:13:03,469 --> 01:13:09,599
okay and so I worked at Goddard in some

1595
01:13:06,689 --> 01:13:11,908
internships and that was really cool

1596
01:13:09,599 --> 01:13:14,400
that was fun and exciting and then when

1597
01:13:11,908 --> 01:13:16,529
I neared the end of undergrad I had to

1598
01:13:14,399 --> 01:13:18,238
do an engineering honors thesis and

1599
01:13:16,529 --> 01:13:20,460
again a friend of mine who was an

1600
01:13:18,238 --> 01:13:22,259
astronomy major told his professor and

1601
01:13:20,460 --> 01:13:24,300
he called me up and says how would you

1602
01:13:22,260 --> 01:13:26,969
like to do it in in astronomy I was like

1603
01:13:24,300 --> 01:13:28,529
okay it has to have some engineering so

1604
01:13:26,969 --> 01:13:30,779
how about a Radio Astronomy that's like

1605
01:13:28,529 --> 01:13:33,029
okay so I did a radio astronomy project

1606
01:13:30,779 --> 01:13:35,009
and it was really cool I thought wow

1607
01:13:33,029 --> 01:13:38,880
well you know I think I want to go into

1608
01:13:35,010 --> 01:13:41,760
grad school this is pretty cool maybe

1609
01:13:38,880 --> 01:13:43,289
I'll try it out for a year so I tried it

1610
01:13:41,760 --> 01:13:44,789
out for a year in grad school and said

1611
01:13:43,289 --> 01:13:46,979
if no if I really don't like it I'm just

1612
01:13:44,789 --> 01:13:47,309
I'm just gonna move over but I really

1613
01:13:46,979 --> 01:13:51,029
like

1614
01:13:47,309 --> 01:13:52,619
so I stuck with it you know all right

1615
01:13:51,029 --> 01:13:55,859
that sounds like a wonderful finish

1616
01:13:52,618 --> 01:13:58,439
point I am sorry to tell you that clouds

1617
01:13:55,859 --> 01:14:00,658
have come in and Duncan sent me an email

1618
01:13:58,439 --> 01:14:04,678
and we are not going across the street

1619
01:14:00,658 --> 01:14:07,698
to the observatory however I did go out

1620
01:14:04,679 --> 01:14:11,158
during market stalk and get you a

1621
01:14:07,698 --> 01:14:13,408
picture for tonight pillar in the Korean

1622
01:14:11,158 --> 01:14:17,029
and nebula all sorts of information on

1623
01:14:13,408 --> 01:14:19,439
the back some over there some here

1624
01:14:17,029 --> 01:14:21,149
remember to check the website for

1625

01:14:19,439 --> 01:14:23,519
whether or not the south or the north is

1626
01:14:21,149 --> 01:14:25,799
closed next month I'll send it out on

1627
01:14:23,520 --> 01:14:27,150
the email thank you all for coming we'll

1628
01:14:25,800 --> 01:14:29,538
see you in September

1629
01:14:27,149 --> 01:14:29,538
take care

1630
01:14:40,210 --> 01:14:49,989
I wonder if I might an average basis

1631
01:14:44,409 --> 01:14:51,639
with even someone for a large or could

1632
01:14:49,988 --> 01:14:55,049
asteroids account for it I told them

1633
01:14:51,640 --> 01:14:55,050
that it's not really your field